# PHILOSOPHICAL TRANSACTIONS,

OF THE

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# PHILOSOPHICAL TRANSACTIONS,

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OF

# L O N D O N.

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# PHILOSOPHICAL TRANSACTIONS.

## XI. *Experiments on the Phlogiſtication of Spirit of Nitre.* *By the Rev.* Joſeph Prieſtley, *LL.D. F. R. S.*

Read March 26, 1789.

AS the colouring of ſpirit of nitre has ſome connection with the doctrine of phlogiſton, to which I propoſe to give my beſt attention, I have lately reſumed my experiments on that ſubject, and beg leave to lay the reſult of them before the Society.

In my former experiments, vol. IV. p. 2. I found that the colourleſs acid became ſmoking, or orange-coloured, and emitted orange-coloured vapours, on being expoſed to heat in long glaſs tubes, hermetically ſealed; and I then concluded, that

this effect was produced by the action of *heat*, evolving, as it were, the phlogiſton previouſly contained in the acid. Afterwards, having found that it was not *heat*, but *light* only, that was capable of giving colour to ſpirit of nitre, contained in phials with ground ſtoppers, in the courſe of ſeveral days; and that in this caſe the effect was produced by the action of *light* upon the *vapour*, which gradually imparted its colour to the liquor on which it was incumbent (ſee Vol. V. p. 342.), I was led to ſuſpect, that as the glaſs tubes, in which I had formerly expoſed this acid to the action of heat, were only held near to a fire, in the day-light, or candle-light, it might have been this *light*, which, in theſe circumſtances, had, at leaſt in part, contributed to produce the effect.

In order to aſcertain whether the light had had any influence in this caſe, I now put the colourleſs ſpirit of nitre into long glaſs tubes, like thoſe which I had uſed before, and alſo ſealed them hermetically, as I had done the others; but, inſtead of expoſing them to heat in the open air, from which light could not be excluded, I now ſhut them up in gun barrels, cloſed with metal ſcrews, ſo that it was impoſſible for any particle of light to have acceſs to them; and I then placed one end of the barrels ſo near to a fire as was ſufficient to make the liquor contained in the tube to boil, which I could eaſily diſtinguiſh by the ſound which it yielded. The conſequence was, that in a ſhort time the acid became as highly coloured as ever it had been when expoſed to heat without the gun barrel. It was evident, therefore, that it had been mere *heat*, and not *light*, which had been the means of giving this colour to the acid, and which has been uſually termed *phlogiſticating* it.

When

When I made the former experiments, I had no ſuſpicion that the *air* contained in the tube had any concern in the reſult of them; and, in thoſe which I made in the phials in a moderate heat, I found that the acid received its colour when the beſt *vacuum* that I could make with an air pump was over it.

My friend Mr. KIRWAN, however, having always ſuſpected, that the *air* was a principal agent in the buſineſs, I at this time gave particular attention to this circumſtance; ſuppoſing that, if any part of the common air had been imbibed, it muſt have been the *phlogiſticated*, and that it was the phlogiſton from this kind of air which had phlogiſticated the acid. The real reſult, however, was not ſo much in favour of this ſuppoſition as I had expected; for the principal effect of the proceſs was the emiſſion of dephlogiſticated air, ſo that the acid ſeems to become what we call phlogiſticated, by parting with this ingredient in its compoſition.

I put a ſmall quantity of the colourleſs acid into a long glaſs tube, which beſides the acid would have contained 1.23 ounce meaſures of common air, but that the vapour of the acid excluded about one-twentieth of the quantity. Having ſealed the tube hermetically, I ſhut it up in a gun barrel, in the manner mentioned above, and expoſed it to a boiling heat for ſeveral hours, and then opening it under water there came out of it 2.03 ounce meaſures of air, very turbid and white; and when it was examined, it appeared to be of the ſtandard of 1.02, with two equal meaſures of nitrous air; when with one meaſure of the ſame nitrous air the ſtandard of the common air was 1.07. The quantity of phlogiſticated air abſorbed in this experiment I aſcertained by the following computation.

As one meaſure of common air, and an equal quantity of nitrous air were reduced to 1.07 m. it is evident, that 0.93 m.

had diſappeared; but as this was effected by the nitrous air uniting with all the dephlogiſticated air contained in the common maſs, and as they unite in the proportion of one meaſure of dephlogiſticated air to two meaſures of nitrous air, one-third of the 0.93 m. *viz.* 0.31 m. will be the quantity of dephlogiſticated air that was contained in the one meaſure of common air on which the experiment was made, the remainder, *viz.* 0.69, having been phlogiſticated air. The common air contained in the tube would have been 1.23 oz. m.; but deducting from it one-twentieth in the whole, it will only be 1.17 oz. m. I then ſay, if one meaſure of this air contains 0.69 m. of phlogiſticated air, 1.17 oz. m. will contain 0.8073 oz. m. of phlogiſticated air. This, therefore, was the quantity of phlogiſticated air which had been expoſed to the action of the acid of nitre in the tube.

In order to find how much of the ſame kind of air was contained in the tube *after* the proceſs, I examined the reſult above mentioned in the following manner. Since two meaſures of nitrous air, and one of this reſiduum, were reduced to 1.02 m. it is evident, that 1.98 m. had diſappeared, and conſequently one-third of this quantity, *viz.* 0.66 m. had been dephlogiſticated air, and that the remainder of the meaſure, *viz.* 0.34, had been the proportion of phlogiſticated air in one meaſure of this reſiduum. If then one meaſure of this reſiduum contains 0.34 m. of phlogiſticated air, 2.03 oz. m. will contain 0.6902 oz. m. which is leſs than 0.8073 oz. m. the quantity contained in it before the proceſs; ſo that a part of the phlogiſticated air had been either abſorbed or decompoſed, its phlogiſton having been imbibed by the acid at the ſame time that it had emitted the dephlogiſticated air.

In

In another proceſs, of the ſame kind, the glaſs tube contained 0.92 oz. m. of common air, and the air that came out of it after the proceſs was one ounce meaſure, of the ſtandard of 1.6 with two meaſures of nitrous air, and computing as I did before, the phlogiſticated air in the tube before the proceſs was 0.6072 oz. m., and after the proceſs 0.54 oz. m.

In theſe computations it is ſuppoſed, that the air emitted by the acid was perfectly pure, ſo that all the phlogiſticated air that is found after the proceſs is ſuppoſed to have been contained in the common air confined in the tube before it was commenced. But I found, that the air emitted by the acid is by no means perfectly pure, ſo that much of the impurity muſt be aſcribed to this circumſtance.

In order to exclude all air from the contact of the acid, I made a quantity of it to boil in the tube, and when the vapour had expelled all the air, I ſealed it hermetically, in the manner in which water hammers are made; and then expoſing it to heat, found that it acquired as high a colour as when air had been confined along with it; ſo that it is evident, that *air* is not neceſſary to this effect. When the tube was opened under water, a quantity of dephlogiſticated air ruſhed out, exceedingly white as before; but when I examined it, I found it to be of the ſtandard of only 0.66. When this impurity is conſidered, it will appear, that when much air is yielded in this proceſs, ſome phlogiſticated air may have been imbibed, though, computing in the manner above mentioned, the phlogiſticated air after the proceſs ſhould be in greater quantity than was contained in the tube before it, as was the caſe in the following experiment.

In a glaſs tube which, beſides the acid, contained 1.13 oz. m. of common air, I expoſed colourleſs ſpirit of nitre to heat

till it became of a deep orange colour; and when it was opened under water, there came out of it 2.83 oz. m. of air exceedingly turbid, of the ſtandard of 0.66, with two equal quantities of nitrous air, when that of the common air, with one equal quantity of nitrous air, was 1.07. Computing in the manner above mentioned, there was in the tube before the proceſs 0.7477 oz. m. of phlogiſticated air, and after the proceſs 0.8792 oz. m. But the dephlogiſticated air, amounting to 1.7 oz. m. being of the ſtandard of 0.66, will be found to contain 0.374 oz. m. of phlogiſticated air, which being deducted from 0.8792, there will remain only 0.5052 oz. m. which is conſiderably leſs than 0.7477 oz. m.

That the nitrous acid can become coloured, without imbibing any thing from phlogiſticated air, is evident not only from its becoming ſo when heated *in vacuo*, as deſcribed above, but alſo, when it was in contact with any other kind of air, as free from phlogiſticated air as I could make it. But from the manner in which theſe experiments were neceſſarily made, it was impoſſible intirely to exclude phlogiſticated air, either as part of the atmoſpheric air, or as contained in the impurities of the air that I made uſe of; for I firſt filled the tube with ſpirit of nitre, then plunging the orifice of it in a veſſel of the ſame, I introduced a quantity of the air which I wiſhed to expoſe to it. After this, putting my finger upon the orifice, I turned it upſide down, and applying to it the cloſed end of a glaſs tube, of about the ſame diameter, I ſealed it hermetically with a blow-pipe as expeditiouſly as I could. This is a neceſſary imperfection in the experiment; but I know not how to remedy it, if any of the acid is to be left in the tube. However, the phlogiſticated air introduced in this manner from the atmoſphere muſt have borne a very ſmall proportion to the air in

the tube; and ſome objection will always remain to the experiment from the impurity of the air made uſe of.

Having repeatedly obſerved, that the acid became coloured in conſequence of being expoſed to heat in contact with any kind of air whatever, I expoſed at the ſame time, and in the ſame circumſtances, three equal quantities of the ſame colourleſs ſpirit of nitre, in three nearly equal tubes, one containing dephlogiſticated, another phlogiſticated, and a third inflammable air; that, if there ſhould be any difference in the colouring of the acid in theſe caſes, it might be the more eaſily perceived. But though I gave all the attention that I could, I did not perceive that there was any difference, except what aroſe from ſome of the tubes being placed a little nearer the fire than the reſt; and, by changing their places, the colour was at length the very ſame in them all.

As in theſe three caſes I examined the air before and after the proceſs, in the manner above mentioned, I ſhall juſt recite the particulars.

Of the dephlogiſticated air the tube contained before the proceſs 1.46 oz. m. of the ſtandard of 0.67, and after the proceſs it contained 1.76 oz. m. of the ſtandard of 0.77; a difference owing in part to the mixture of common air, which could not be excluded in the ſealing of the tube, and in part to the air emitted from the acid not being pure.

Of the phlogiſticated air, the tube contained 1.3 oz. m. and after the proceſs 1.95 oz. m. of the ſtandard of 1.38.

Of the inflammable air, the tube contained before the proceſs 1.52 oz. m. and after the proceſs 1.9 oz. m. of the ſtandard of 1.8. They were all meaſured by a mixture of two equal quantities of nitrous air.

If

If theſe reſults be examined as that of the firſt experiment, with common air, it will be found that, in all theſe proceſſes, there was leſs phlogiſticated air, or inflammable air, after the proceſs than before; and this reſult being thus uniform, I cannot help concluding, that this kind of air is in part decompoſed, and purified by this means; ſo that by this emiſſion of dephlogiſticated air which the heat expels from the acid, ſomething, and probably phlogiſton, is at the ſame time imbibed from it; which proves that phlogiſticated air is no ſimple ſubſtance, but a compound, and that phlogiſton is one conſtituent part of it; for this acid acquires the ſame colour, and all the ſame properties, by adding to it any thing that is ſuppoſed to contain phlogiſton.

As the ſpirit of nitre can be rendered ſmoking, or phlogiſticated, by the mere expulſion of dephlogiſticated air, it is evident, that it contains two principles in cloſe affinity with each other, and that nothing is neceſſary to render either of them conſpicuous beſides the abſence of the other.

It is alſo natural to ſuppoſe, that, for the ſame reaſon that the *dephlogiſticating* principle (as it may be called) is expelled, the *phlogiſticating* principle ſhould enter; ſo that the purification of the air in contact with the acid may be a neceſſary conſequence of the expulſion of the pure air contained in it, the whole tending, as it were, to an equilibrium in this reſpect. It is therefore by no means difficult to conceive, that phlogiſton ſhould be extracted from the contiguous air at the ſame time that the dephlogiſticated air *not pure* (that is, containing a mixture of phlogiſticated air) is driven out of it; for the acid always containing phlogiſtion, whatever air is contained in it, and expelled from it, may neceſſarily contain phlogiſton or phlogiſticated air; but the purer air may be emitted, and the

leſs

leſs pure air be imbibed, till the whole come to be of the ſame quality. It may, however, perhaps follow from the emiſſion of impure dephlogiſticated air, and the imbibing of phlogiſticated air at the ſame time, that the former does not conſiſt of dephlogiſticated and phlogiſticated air looſely mixed, but of ſome intimate union of dephlogiſticated air with phlogiſton, though they may be ſeparated by a mixture of nitrous air, and other proceſſes, in the very ſame manner as dephlogiſticated air may be ſeparated from a looſe mixture of phlogiſticated air.

It is evident from theſe experiments, that a red heat is not neceſſary to the converſion of nitrous acid into pure air, though this proceſs, as appeared by my former experiments, produces this effect moſt quickly and effectually.

I cannot help conſidering the experiments above recited to be favourable to the doctrine of the phlogiſton, and unfavourable to that of the decompoſition of water, though not deciſively ſo; for ſince the red vapour of ſpirit of nitre unqueſtionably contains the ſame principle that has been termed phlogiſton, or the principal element in the conſtitution of inflammable air, and according to the antiphlogiſtians this is one conſtituent part of water, they muſt ſuppoſe, that the water in this acid is decompoſed by a much more moderate heat than in moſt other caſes. In general, I believe, they have thought a red heat to be neceſſary for this purpoſe. It is evident, that the converſion of water into ſteam by boiling, or by any heat that can be given to it under the ſtrongeſt preſſure, has no tendency whatever to decompoſe it. But if the mere boiling of water in nitrous acid could produce this effect, I do not ſee why the ſame ſhould not be the caſe when water alone is boiled.

I think it will alſo be more difficult to explain the purification of the incumbent atmoſpherical air on the antiphlogiſtic

than on the phlogiſtic hypotheſis, whatever be the conſtitution of phlogiſticated air.

As, in the experiments above mentioned, *heat* without *light* gives colour to the nitrous acid, and the reflection or refraction of light is always attended with heat, it may perhaps be *heat* univerſally that is the means of imparting this colour, though the mode of its operation be at preſent unknown. And in theſe experiments, as well as the former, it is the *vapour* that firſt receives the colour, and imparts it to the liquid when it is ſufficiently cold to receive it.

The ruſhing out of a quantity of turbid white air from a tranſparent tube, quite cold, is a ſtriking phænomenon in theſe experiments. It may be worth while to examine of what it is that this remarkable cloudineſs of the air conſiſts. There is the ſame appearance, as I have more than once obſerved, in the rapid production of any kind of air, which is perfectly tranſparent as it paſſes along the glaſs tube through which it is tranſmitted, till it comes into contact with the water in which it is received.

P. S. Not to multiply my communications on the ſubject of *phlogiſton* unneceſſarily, I would beg leave to obſerve, at the cloſe of this article (in reply to what has been objected to my former experiments, as being liable to exception from the phlogiſticated air which could not be excluded from the dephlogiſticated air when it was decompoſed by means of inflammable air) that I have found the proceſs I made uſe of to have no tendency whatever to decompoſe phlogiſticated air. Indeed, nothing that we have hitherto known concerning this kind of air could make it probable, that mere *heat*, in contact with dephlogiſticated or inflammable air, *could* have this effect. And

it is of no conſequence whatever to ſay, that any particular ſubſtance, imagined to be decompoſed, is *preſent* in a proceſs, unleſs it can be ſhewn that, in that proceſs, there are agents capable of decompoſing it. If mere *heat* (which is all that my proceſs requires) would decompoſe phlogiſticated air, and reduce it to nitrous acid, the tranſmiſſion of common air (which conſiſts of dephlogiſticated and phlogiſticated air) through a red hot tube would have this effect, which it is well known not to have.

But what I have aſſerted above is a concluſion which I have drawn from comparing the decompoſition of dephlogiſticated air by the two proceſſes with nitrous and inflammable air. That nitrous air, when mixed with dephlogiſticated air, has no tendency to produce phlogiſticated air, is evident from the almoſt total evaneſcence of both of them, when they are very pure, and mixed in due proportions; and that nitrous air has no effect on phlogiſticated air is well known. If then the firing of dephlogiſticated and inflammable air had a tendency to decompoſe any portion of phlogiſticated air, which ſhould happen to be mixed with them, leſs would remain after the firing of inflammable and impure dephlogiſticated air than after mixing it with nitrous air; for as the impurities of dephlogiſticated air conſiſt of phlogiſticated air, thoſe would diſappear in a greater proportion in the former proceſs than in the latter. But by many careful trials I find, that I can reduce any kind of dephlogiſticated air no farther by a mixture of inflammable air than I can by nitrous air. When the proportions are well managed, the diminution is as nearly as poſſible the ſame in both the caſes.

I muſt obſerve, however, that it requires more nitrous air than inflammable air (from iron by ſteam) to produce this effect

in the proportion of about 10 to 9; ſo that nitrous air does not contain quite ſo much phlogiſton as an equal bulk of inflammable air, as I had before thought to be the caſe.

In this Paper it will be obſerved, that I make the diminution of common air by nitrous air to be conſiderably leſs than I have uſually done before. This has been the conſequence of giving the two kinds of air a little agitation at the inſtant of mixing, which will generally make the diminution leſs by two tenths of a meaſure. But I have found, that when theſe mixtures of air, with and without agitation, have been kept ſome time, they approach to an equality of bulk.

At the ſame time I have obſerved, what I think not a little extraordinary, that agitation prevents the greateſt diminution of dephlogiſticated and nitrous air. I have found it to be 2.5 without agitation, and 6. with it.

The leſs diminution of the mixture of nitrous and common air is probably owing to the preſence of ſo much phlogiſticated air, which impedes the meeting of the nitrous air with the dephlogiſticated air in the mixture; becauſe I find the ſame to be the caſe when I mix the ſame proportion of inflammable air with dephlogiſticated air; and when dephlogiſticated air is agitated with nitrous air, the *water* may impede their union, as the phlogiſticated air did before.

There is, therefore, no ſource of the *nitrous acid* which I find on the decompoſition of dephlogiſticated and inflammable air, beſides the union of thoſe two kinds of air, which therefore do not make *mere water*, as the antiphlogiſtians ſuppoſe.

XII. *Obſervations on a Comet. In a Letter from* William Herſchel, *LL.D. F. R. S. to Sir* Joſeph Banks, *Bart. P. R. S.*

Read April 2, 1789.

SIR, Slough, March 3, 1789.

THE laſt time I was in town, you expreſſed a wiſh to ſee my obſervations on the comet which my ſiſter, CAROLINE HERSCHEL, diſcovered in the evening of the 21ſt of laſt December, not far from $\beta$ Lyræ.

As ſhe immediately acquainted the Rev. Dr. MASKELYNE, and ſeveral other gentlemen, with her diſcovery, the comet was obſerved by many of them. The Aſtronomer Royal, in particular, having, I find, obtained a very good ſet of valuable obſervations on its path, it will be ſufficient if I communicate only thoſe particulars which relate to its firſt appearance, and a few other circumſtances that may perhaps deſerve to be noticed.

December 21, 1788, about 8 o'clock, I viewed the comet which my ſiſter had a little while before pointed out to me with her ſmall Newtonian *ſweeper*. In my inſtrument, which was a ten-feet reflector, it had the appearance of a conſiderably bright nebula; of an irregular, round form; very gradually brighter in the middle; and about five or ſix minutes in diameter. The ſituation was low, and not very proper for inſtruments with high powers.

December 22, about half after five o'clock in the morning, I viewed it again, and perceived that it had moved apparently in a direction towards $\delta$ Lyræ, or thereabout. I had been engaged all night with the twenty-feet inſtrument, ſo that there had been no leiſure to prepare my apparatus for taking the place of the comet; but in the evening of the ſame day, I took its ſituation three times, as follows:

| | h. ′ ″ | |
|---|---|---|
| Dec. 22. at | 23 42 19 | ſidereal time, the comet paſſed the wire, |
| at | 23 49 24 | $\beta$ Lyræ paſſed the ſame, |
| Difference | 7 5 | very accurate. |
| at | 23 52 52 | the comet paſſed, |
| at | 23 59 58 | $\beta$ Lyræ paſſed, |
| Difference | 7 6 | accurate. |
| at | 0 6 35 | the comet paſſed, |
| at | 0 13 40 | $\beta$ Lyræ paſſed, |
| Difference | 7 5 | very accurate. |

I found in every obſervation the ſmall ſtar which accompanies $\beta$ Lyræ *, exactly in the parallel of the comet.

Theſe tranſits were taken with a ten-feet reflector; and the difference in right aſcenſion, I ſhould ſuppoſe, may be depended upon to within a ſecond of time. The determination

* For this ſmall ſtar ſee my Catalogue of Double Stars, in the Philoſophical Tranſactions for the year 1782, Part I. Claſs V. Star 3. where its diſtance and poſition are given, and conſequently its parallel may be found.

alſo

alſo of the parallel can hardly err ſo much as fifteen ſeconds of a degree.

This, and ſeveral evenings afterwards, I viewed the comet again with ſuch powers as its diluted light would permit, but could not perceive any ſort of nucleus, which, had it been a ſingle ſecond in diameter, I think, could not well have eſcaped me. This circumſtance ſeems to be of ſome conſequence to thoſe who turn their thoughts on the inveſtigation of the nature of comets; eſpecially as I have alſo formerly made the ſame remark on one of the comets diſcovered by M. MECHAIN in 1787, a former one of my ſiſter's in 1786, and one of Mr. PIGOTT's in 1783; in neither of which any defined, ſolid nucleus could be perceived.

I have the honour to remain, &c.

WILLIAM HERSCHEL.

| Dates. | Snow-drop flower. | Thrush sings. | Hawthorn leaf. | Hawthorn flower. | Frogs and Toads croak. | Sycamore leaf. | Birch leaf | Elm leaf. | Mountain-ash leaf. | Oak leaf. | Beech leaf. | Horse-chesnut leaf. | Ch l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1736 | | 1735 Dec. 4. | | | | | | | | | | | |
| 1738 | | | | Nismes, France, Apr. 14, N.S. | | | | | | | | | |
| 1739 | | | Feb. 23. | | | Feb. 23. | | | | | | | |
| 1740 | | Feb. 27. | April 4. | May 28. | | April 14. | | | | | | | |
| 1741 | | | | May 9. | March 12. | | | | | | | | |
| 1742 | | Jan. 31. | | May 15. | April 11. | | | | | | | | |
| 1743 | | Jan. 31. | | May 8. | Feb. 28. | | | | | | | | |
| 1744 | | | March 28. | Essex, May 12. | March 28. | March 30. | | | | | | | |
| 1745 | Jan. 6. | Jan. 26. | March 26. | May 13. | March 14. | March 29. | March 29. | | | | | March 29 | |
| 1746 | Jan. 20. | | March 26. | May 13. | March 15. | April 10. | April 10. | | | May 1. | May 1. | | |
| 1747 | Jan. 8. | Jan. 14. | Feb. 15. | April 26. | Feb. 24. | March 25. | March 29. | | | April 23. | April 26. | | |
| 1748 | Jan. 5. | Jan. 29. | April 3. | Middlesex, May 22. | March 28. | April 14. | April 10. | | | | | | |
| 1749 | Jan. 4. | Jan. 17. | Feb. 19. | Middlesex, May 1. | March 5. | March 18. | March 24. | | | April 22. | April 22. | | |
| 1750 | Jan. 15. | Jan. 17. | Feb. 13. | April 13. | Feb. 20. | Feb. 22. | Feb. 21. | | | March 31. | April 15. | | |
| 1751 | Jan. 9. | Jan. 2. | March 10 | May 9. | March 27. | | March 22. | March 6. | | April 25. | April 24. | March 21. | |
| 1752 | | Jan. 30. | Middlesex, Feb. 18. | May 14. | March 9. | April 6. | April 2. | | | April 20. | April 20. | March 19. | |
| N. Style 1753 | Feb. 1. | Feb. 1. | March 21. | May 11. | April 1. | April 3. | March 27. | | | April 24. | April 29. | | |
| 1754 | Jan 18. | Feb. 16. | April 7. | May 22. | April 6. | April 14. | April 14. | | | May 11. | May 7. | | |
| 1755 | Jan. 26. | Feb. 16. | March 31. | May 10 | April 1. | April 9. | April 1. | April 10. | April 9. | April 18. | April 21. | March 31. | Ap |

: Marsham, *Esquire, F. R. S. of* Stratton *in* Norfolk. *Latitude* 52° 45'.

Read April 2, 1789.

| | Chesnut leaf. | Hornbeam leaf. | Ash leaf. | Ringdoves coo. | Rooks build. | Young Rooks. | Swallows appear. | Cuckoo sings. | Nightingale sings | Churn Owl sings. | Yellow Butterfly appears. | Turnip in flower. | Lime leaf. | Maple leaf. | Wood Anemone flower. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | March 30. | | | | | | | | |
| | | | | | | | Piacenza, Italy, Mar. 20, N. S. | | | | | | | | |
| | | | | | | | April 13. | April 19. | April 25. | | | Feb. 21. | | | |
| | | | | | Feb. 27. | | March 31. | April 14. | May 2. | May 21. | | May 2. | | | |
| | | | | Feb. 2. | Feb. 13. | April 2. | April 9. | April 19. | April 14. | | | | | | |
| | | | | | | April 1. | April 17. | April 17. | April 21. | | | April 15. | | | |
| | | | | | | | April 12. | April 17. | April 20. | | | March 23. | | | |
| | | | | | Feb. 21. | April 1. | March 31. | April 20. | April 9. | May 23. | | April 8. | | | |
| 29 | | | | Jan. 3. | March 8. | April 8. | April 3. | April 22. | April 12. | May 10. | | April 8. | | | |
| | | | | | Feb. 25. | March 31. | April 8. | April 16. | April 19. | May 5. | | April 16. | May 1. | | |
| | | | | Jan. 13. | Feb. 13. | March 26. | April 2. | April 22. | April 15. | May 9. | | March 18. | | | |
| | | | | Feb. 8. | Feb. 29. | April 3. | April 2. | April 16. | April 23. | May 28. | | April 22. | | | |
| | | | | Feb. 13. | Feb. 18. | March 29. | April 5. | April 13. | April 16. | May 20. | | March 9. | | | |
| | | | | Jan. 22. | Feb. 13. | March 30. | April 8. | April 11. | April 9. | May 17. | Feb. 9. | Feb. 22. | | | |
| 21. | | | April 16. | 1750 Dec. 29. | March 3. | April 7. | | April 19. | April 16 | May 3. | | March 29. | | | |
| 19. | | | | 1751 Dec. 27. | | March 29. | April 2. | April 9. | April 7. | May 12. | | April 6. | | | |
| | | | May 11. | Feb. 22. | March 3. | April 15. | April 17. | April 24. | April 19. | | | March 30. | | | |
| | | | | | March 1. | April 11. | April 13 | April 24. | April 11. | May 16 | | May 9 | | | |
| 31. | April 16. | April 13. | April 22. | March 4. | March 14. | April 18. | April 6. | April 23. | April 14 | June 4. | | April 15. | April 12. | April 18. | |

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| Dates. | Snow-drop flower. | Thrush sings. | Hawthorn leaf. | Hawthorn flower. | Frogs and Toads croak. | Sycamore leaf. | Birch leaf. | Elm leaf. | Mountain-ash leaf. | Oak leaf. | Beech leaf. | Horse-chesnut leaf. | Che lea |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1756 | Jan. 8. | Jan. 30. | Feb. 26. | May 25. | March 10. | April 1. | March 11 | March 30. | April 5. | May 7. | May 7 | | |
| 1757 | Feb. 6. | Feb. 16. | March 20. | May 19. | March 29. | April 1. | March 29. | April 1. | March 31. | April 26. | April 29. | | |
| 1758 | Jan. 9. | Feb. 2. | March 19. | May 13. | March 16. | April 1. | April 1. | April 1. | April 13. | April 29. | April 27. | April 13. | |
| 1759 | Jan. 9. | Jan. 17. | Feb. 11. | May 6. | March 1. | Middlesex, March 22. | Middlesex, March 31. | Middlesex, March 19. | April 1. | April 15. | April 25. | Middlesex, March 25. | April |
| 1760 | Jan. 24. | Feb. 10. | Kent, March 7. | April 27. | March 15. | April 3. | April 2. | April 9. | April 2. | April 19. | April 19. | April 12. | April |
| 1761 | | Jan. 4. | Surrey, Feb. 27. | May 4. | March 22. | March 25 | March 24. | Surrey, Feb. 27, | March 25. | April 14. | April 20. | March 29. | April |
| 1762 | Jan. 12. | Jan. 22. | Surrey, March 7. | May 4. | April 19. | Middlesex, April 16. | April 6. | Middlesex, April 12. | April 19. | April 22. | April 21. | Middlesex, April 16. | April |
| 1763 | | London, Feb. 11. | Surrey, Feb. 26. | May 7. | March 30. | March 28. | March 25 | April 1. | March 28. | April 24. | April 20. | Surrey, March 10. | April |
| 1764 | Jan. 6. | Jan. 9. | Feb. 17. | Middlesex. May 17. | | | | London, March 21. | Surrey, April 8. | Herts. April 24. | Herts. April 24. | Surrey, April 8. | |
| 1765 | Jan. 5. | Feb. 11. | March 16. | Kent, May 11. | March 23. | Middlesex, April 7. | | Middlesex, March 29. | | Herts. May 1. | Herts. May 1. | Middlesex, March 31. | |
| 1766 | | Feb. 23. | March 16. | | March 9. | Surrey, April 13. | March 11. | Middlesex April 12. | Surrey, May 2. | Surrey, May 2. | | Surrey, April 13. | |
| 1767 | Jan. 28 | Feb. 1. | Surrey, March 12 | May 29. | | Surrey, April 19. | Surrey, April 19. | Middlesex, March 14. | | Essex, May 3. | May 5. | Middlesex, April 8. | |
| 1768 | Jan. 28. | | Surrey, Feb. 28. | May 11. | March 17. | March 23. | March 21. | April 4. | April 4. | April 24. | April 24. | April 4. | |
| 1769 | Jan. 13. | | Essex. March 4. | Essex, May 4. | | Middlesex, April 17. | | Kent, March 25. | Middlesex, April 6. | Kent, April 25. | | Middlesex, April 6. | Ken April |
| 1770 | Jan. 21. | Jan. 28. | Surrey, March 11. | May 22. | | Middlesex, April 23. | May 1. | Middlesex, March 11. | May 1. | May 11. | May 6. | Middlesex, April 8. | May |

cations of Spring continued.

| Chesnut leaf. | Hornbeam leaf. | Ash leaf. | Ringdoves coo. | Rooks build. | Young Rooks. | Swallows appear. | Cuckoo sings. | Nightingale sings. | Churn Owl sings. | Yellow Butterfly appears. | Turnip in flower. | Lime leaf. | Maple leaf. | Wood Anemone flower. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Feb. 22. | March 1. | April 8, | April 7. | April 18. | April 14. | May 16. | | 1755, Dec. 28. and March 4. | May 7. | | |
| | | May 1. | Mar. 10. | March 13. | April 18. | April 16. | April 26. | April 16. | May 17. | | April 11. | | | |
| | March 15. | May 8. | March 3. | March 5. | April 13. | April 10. | April 30. | Middlesex, April 23. | May 18. | March 15. | April 14. | | | |
| April 21. | Middlesex, March 30. | April 23. | Feb. 11. | Feb. 28. | April 10. | April 10. | April 26. | April 21. | June 6. | | Feb. 27 | April 18. | April 18. | |
| April 19. | April 13. | April 19. | | Middlesex, March 12. | April 11. | April 11. | April 21. | April 21. | May 29. | | April 13. | April 19. | April 13. | |
| April 10. | April 10. | May 3. | March 20. | Essex, March 11. | April 7. | April 5. | May 2. | April 17. | May 30. | March 12. | Jan. 15. | April 4. | April 17. | March 29. |
| April 20. | Herts. April 18 | April 25. | | | April 20. | April 8. | April 20. | April 19. | May 31. | April 5. | April 19. | April 16. | April 21. | |
| April 18. | April 3. | May 7. | | | April 16. | April 5. | April 27. | April 20. | May 31. | | April 17. | April 15. | | |
| | | Kent, May 5. | Feb. 22. | March 6. | | London, April 8. | Herts. April 24. | Kent, May 2. | | | Middlesex, March 18. | | | |
| | | Herts. May 1. | Feb. 25. | March 7. | | Middlesex, April 14. | Middlesex, April 12. | Herts. May 3. | June 4. | | | Middlesex, April 10. | | March 24. |
| | Surrey, May 2. | Surrey, May 2. | March 3. | March 7. | Middlesex, April 24. | Middlesex, April 17. | Surrey, May 2. | Surrey, May 2. | May 26. | March 6 | | Surrey, April 12. | | |
| | | | | | | Surrey, April 23. | May 7. | Essex, May 3. | | | | London, March 22. | | |
| | April 19. | April 27. | | Middlesex, Feb. 29. | April 10. | April 17. | April 24. | April 17. | | | March 28. | April 20. | | |
| Kent, April 25. | | Essex, May 4. | | | | Surrey, April 19. | Kent, April 25. | Sussex, May 23. | June 10. | | | London, April 16. | | |
| May 12. | May 1. | May 12. | | Feb. 23. | | Middlesex, April 23. | May 1. | May 6. | | Feb. 14. | April 23. | May 2. | May 7. | |

| Dates. | Snow-drop flower. | Thruſh ſings. | Hawthorn leaf. | Hawthorn flower. | Frogs and Toads croak. | Sycamore leaf. | Birch leaf. | Elm leaf. | Mountain-aſh leaf. | Oak leaf. | Beech leaf. | Horſe-cheſnut leaf. | Cheſnut leaf. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1771 | Jan. 27. | Feb. 21. | April 11. | May 25. | April 6. | May 4. | May 4. | Middleſex, April 24. | May 2. | May 15. | May 10. | May 2. | May 10. |
| 1772 | Jan. 14. | Feb. 12. | March 22 | May 22. | March 25. | Middleſex, April 13. | | Middleſex, April 8. | Middleſex, April 13. | May 13 | May 3. | Middleſex, April 13. | May 11. |
| 1773 | Jan. 11. | Jan. 26. | March 21. | May 6. | March 18. | April 10. | March 29. | April 6. | April 6. | April 23. | April 29. | April 16. | |
| 1774 | Jan. 28 | Herts. Feb. 17. | Herts. March 4. | May 10. | March 31. | April 3 | March 31. | April 3. | March 31. | April 25. | April 24. | April 8. | |
| 1775 | Jan. 14. | Feb. 9. | Feb. 26. | May 1. | March 5. | March 25. | March 20 | March 19. | March 21. | April 21. | April 25. | Suffolk, March 30. | April 30. |
| 1776 | 1775 Dec. 30. | Feb. 21 | Herts. March 8. | April 28. | March 22. | March 26. | March 19. | March 19. | March 23. | April 15. | April 19. | March 30. | April 21. |
| 1777 | Jan. 17. | Feb. 25. | March 20. | May 6. | March 25. | March 28. | March 26. | April 7. | March 29. | April 22. | April 22. | March 30. | April 25. |
| 1778 | Jan. 26. | Feb. 9. | April 4. | Herts. May 14. | March 19. | April 6. | April 6. | April 12. | April 7. | April 30. | April 15. | April 11. | April 17 |
| 1779 | 1778 Dec. 24. | Feb. 6. | Feb. 22. | April 16. | Feb. 25. | March 7. | March 4. | March 4. | March 5. | March 31. | April 5. | March 25. | April 5. |
| 1780 | Feb. 9. | Feb. 16. | March 15 | May 10. | March 21. | March 25. | March 28. | March 26. | March 28. | April 26. | April 24. | March 22. | April 26 |
| 1781 | Jan. 29. | Feb. 6. | March 9. | April 28. | March 16. | March 22. | March 24. | March 26. | March 24. | April 19. | April 15. | April 10. | April 20 |
| 1782 | Jan. 4. | Feb. 21. | Feb. 20. | May 19. | March 13. | April 3. | April 10 | April 10. | | May 14. | April 25. | April 10. | May 11. |
| 1783 | Jan. 26. | Jan. 31. | Feb. 23. | April 27. | March 10. | April 7. | April 1. | April 2. | April 1. | April 24. | April 19. | April 6. | April 19 |
| 1784 | Feb. 8. | March 4. | April 22. | May 14. | April 18. | April 23. | April 23. | May 6. | April 22. | May 9. | May 1. | April 23. | May 9. |
| 1785 | Jan. 24. | Jan. 24. | April 12. | May 2. | April 8. | April 19. | April 18. | April 19. | April 18. | May 5. | April 23. | April 19. | April 29 |
| 1786 | Jan. 22. | Feb. 15. | March 26. | May 15. | March 19. | April 18. | April 16. | April 19. | April 16. | May 6. | April 28. | April 18. | May 6. |
| 1787 | Jan. 30. | Feb. 4. | Feb. 25. | May 1. | March 21. | March 22. | March 18. | March 18. | March 17. | April 26. | April 25. | March 21. | April 24 |
| 1788 | Jan. 12. | Feb. 12. | March 2. | May 6. | March 24. | April 4. | April 3. | April 10. | April 4. | April 24. | April 18. | April 4. | April 20 |

ons of Spring continued.

| hefnut leaf. | Hornbeam leaf. | Ash leaf. | Ringdoves coo. | Rooks build. | Young Rooks. | Swallows appear. | Cuckoo fings. | Nightingale fings. | Churn Owl fings. | Yellow Butterfly appears. | Turnip in flower. | Lime leaf. | Maple leaf. | Wood Anemone flower. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ay 10. | May 7. | May 16. | Feb. 26. | March 15. | | Middlesex, April 18. | May 5. | May 3. | May 20. | Feb. 18. | May 3. | May 7. | May 7. | April 11. |
| ay 11. | May 3. | May 26. | March 3. | Feb. 19. | | Kent, April 15. | Surrey, April 26. | May 11. | May 17. | March 25. | April 17. | Middlesex, April 18. | May 5. | |
| | April 10. | May 20. | March 3. | March 3. | April 10. | April 16. | April 22. | Essex, May 20. | June 2. | March 3. | March 24. | April 21. | April 19. | April 8. |
| | April 16. | April 27. | | | April 11. | April 21. | April 26. | April 30. | May 6. | Herts, March 4 | April 6. | April 8. | April 24. | March 26. |
| pril 30. | Cambridgesh. March 31. | May 2. | Feb. 15. | Feb. 26. | April 15. | Suffolk, April 14. | April 23. | May 7. | May 15. | Feb. 26. | March 15 | Cambridgesh. March 31. | Herts. April 7. | March 9. |
| pril 21. | April 2. | April 23. | Feb. 14. | March 13. | April 2. | April 8. | April 21. | April 17. | May 26. | March 22. | April 7. | April 12. | April 6. | April 3. |
| pril 25. | April 11. | May 4. | Feb. 28. | Feb. 26. | April 6. | April 13. | April 20. | May 8. | May 20. | Feb. 27. | April 7. | April 10. | April 22. | |
| pril 17. | April 12. | April 25. | Feb. 9. | March 5. | April 12. | April 21. | April 30. | May 5. | May 27. | March 18. | April 14. | | April 13. | April 5. |
| April 5. | March 24. | April 2. | Feb. 25. | March 1. | April 4. | April 13. | April 25. | May 9. | May 19. | Feb. 18. | Feb. 28. | April 1. | March 31. | March 15. |
| pril 26. | March 29. | May 1. | March 8. | March 1. | April 6. | April 22. | April 22. | | April 30. | March 8. | April 30. | April 2. | April 22. | March 29. |
| pril 20. | April 3. | April 19. | Feb. 9. | March 1. | April 6. | April 11. | April 16. | April 24. | April 29. | March 9. | April 7. | April 6. | April 15. | March 26. |
| May 11. | April 22. | May 16. | Feb. 27. | Feb. 27. | April 10. | April 22. | April 22. | May 8. | May 27. | April 7. | April 10. | May 5. | April 27. | April 12. |
| pril 19. | April 14. | April 20. | Feb. 14. | March 9. | April 12. | April 20. | April 28. | April 12. | May 15. | March 18 | March 23. | April 2. | April 18. | April 1. |
| May 9. | April 27. | May 12. | March 7. | March 2. | April 9. | April 19. | April 26. | April 28. | May 16 | April 17. | May 14. | May 4. | April 27. | April 22. |
| pril 29. | April 19. | May 2. | March 18. | March 14. | April 16. | April 12. | April 27. | April 23. | May 18. | March 19. | April 27. | April 22. | April 24 | April 16. |
| May 6. | April 18. | May 2. | March 12. | Feb. 3. | April 13. | April 21. | April 30. | April 22. | June 4. | March 12. | April 25. | April 20. | April 21. | April 11. |
| pril 24. | March 18. | April 29. | March 9. | March 7. | April 15. | April 18. | May 2. | April 27. | June 4. | Feb. 18. | March 22. | March 29. | April 26. | March 16. |
| pril 20. | April 4. | April 20. | March 11. | Feb. 26. | April 14. | April 11. | April 21. | April 27. | May 23. | March 28. | April 13 | April 11. | April 12. | March 30. |

## XIV. *An Account of a Monſter of the human Species, in two Letters; one from Baron* Reichel *to Sir* Joſeph Banks, *Bart. and the other from Mr.* James Anderſon *to Baron* Reichel. *Communicated by Sir* Joſeph Banks, *Bart. P. R. S.*

Read April 30, 1789.

TO SIR JOSEPH BANKS, BART.

SIR, Fort St. George, Feb. 28, 1788.

I HAVE the pleaſure to tranſmit to you the portrait of a Gentoo boy, an aſtoniſhing living ſubject, who being ſent to me by a friend of mine reſiding in the environs of the native place of the boy, I made two drawings repreſenting the alternate attitudes in which he can place half the body of his little brother, who adheres to his breaſt. See Tab. II. PERUNTALOO is a handſome well-made lad, poſſeſſing every due faculty of mind and body, rather more ſagacious, and with a ſuperior ſhare of underſtanding, than young men in general of his age. In addition to the incloſed anatomical deſcription of the boy by Mr. ANDERSON, you will obſerve in the drawings two circular dotted lines, about the lower part of the loins of the ſemi-monſter. During the ſeveral ſittings I had of PERUNTALOO, I obſerved an internal motion about theſe parts rather more conſpicuous than any other of the body; and upon queſtioning the youth, he ſhewed me, that by retaining his breath, he could force a current of air into them, ſo as to ſwell the parts like two blown-up bladders, with a rumbling noiſe at the time of action. Whether there is a connection with the lungs of PERUNTALOO is

a queſtion I cannot venture to determine; Mr. ANDERSON, however, thinks it well worth my mentioning this obſervation. The erection of the little penis in the ſemi-monſter, and the command PERUNTALOO has of diſcharging the urine through it, are perfectly aſcertained.

Such as this ſubject is, if with any merit, you may depend upon the correctneſs of the drawings.

I am, &c.

T. REICHEL.

To BARON REICHEL.

SIR, Fort St. George, Feb. 25, 1788.

AS you mean to ſend the elegant drawing of PERUNTALOO to Sir JOSEPH BANKS, you may acquaint him from me, that the little brother is ſuſpended by the os pubis; an elongation of the ſword-like cartilage of PERUNTALOO having anaſtomoſed with that bone at the ſymphyſis.

The lower orifice of the ſtomach ſeems to lie in the ſac or cylindrical cavity between the two brothers on the right-ſide, and what may be reckoned the right hypochondre of the little one, as that part is tumid and full after eating.

The alimentary canal muſt be common to both, as the anus of the little one is imperforate.

There is a bladder of urine diſtinctly perceived, which occupies the left ſide of the ſac, or left hypochondre of the monſter.

Beſides which, there remain only the ſacrum, oſſa innominata, and lower extremities perfect.

PERUNTALOO

Fig. 1.

Fig. 2.

Drawn from life at Madras 28th Oct. 1787. by T. Reichel.

Basire Sc.

PERUNTALOO ſays he has as complete a ſenſe of feeling with every part of the body of his little brother as of his own proper body, and this may account for the erections you ſaw, and making water diſtinctly; but this volition does not extend to the legs or feet, which are cold in compariſon with the reſt.

I am, &c.

JAMES ANDERSON.

EXPLANATION OF THE PLATE.

PERUNTALOO, ſon of CHINDRAHPAH NAYANDOO, of the Gentoo Caſt. He was born at Popelpahdoo, 70 miles weſt from Muſilipatnam. He is 13 years of age, and meaſures 4 feet 6½ inches in height.

Fig. 1. Natural poſition.

Fig. 2. Reverſed poſition.

## XV. *A ſupplementary Letter on the Identity of the Species of the* Dog, Wolf, *and* Jackal; *from* John Hunter, *Eſq. F. R. S. addreſſed to Sir* Joſeph Banks, *Bart. P. R. S.*

Read April 30, 1789.

SIR,

IN the year 1787 I had the honour of preſenting to this learned Society, a Paper to prove the Wolf, the Jackal, and the Dog to be of the ſame ſpecies. But as the complete proof of the Wolf being a Dog, which conſiſted in the half-bred puppy breeding again, had not been under my own inſpection, although ſufficiently well authenticated, I ſaved a female of one of the half-bred puppies, mentioned in that Paper, in hopes of being myſelf a witneſs of the fact; but when the period of impregnation arrived, we unluckily miſſed that opportunity. However, another half-bred puppy has had young, which is equally ſatisfactory to me as if my own had bred. JOHN SYMMONS, Eſq. of Milbank, has had a female Wolf in his poſſeſſion for ſome time, who was lined by a Dog, and brought forth ſeveral puppies, which I had the honour of ſeeing with you. This was a very ſhort time after the brood had been produced by Mr. GOUGH's Wolf, the ſubject of my former Paper, therefore the puppies were nearly of an age with mine. Theſe puppies Mr. SYMMONS has reared; only one of them was a female, and ſhe had much more of the mother or Wolf in her than any of

the reſt of the ſame litter. I communicated my wiſh to Mr. SYMMONS, that either his puppy or mine ſhould prove the fact to our own knowledge; which he immediately, with great readineſs, acceded to. On the 16th, 17th, and 18th of December, 1788, this bitch was lined by a Dog, and on the 18th of February ſhe brought eight puppies, all of which ſhe now rears. If we reckon from the 16th of December, ſhe went ſixty-four days; but if we reckon from the 17th, the mean time, then it is ſixty-three days, the uſual time for a bitch to go with pup. Theſe puppies are the ſecond remove from the Wolf and Dog, ſimilar to that given by my Lord CLANBRASSIL to the Earl of PEMBROKE, which bred again. (See Philoſophical Tranſactions, Vol. LXXVII. p. 255.) It would have proved the ſame fact if ſhe had been lined by either a Wolf, a Dog, or one of the males of her own litter.

I may juſt remark here, that the Wolf ſeems to have only one time in the year for impregnation natural to her, and that is in the month of December; for every time Mr. GOUGH's Wolf has been in heat was in this month, and it proves to be the ſame month in which Mr. SYMMONS's Wolf was in heat; for his half-bred Wolf is nearly of the ſame age with mine, and the time ſhe was in heat was alſo the ſame with that of her own mother, and the preſent brood correſponds in time with the brood of Mr. GOUGH's Wolf.

I am, &c.

JOHN HUNTER.

XVI. *Abſtract of a Regiſter of the Barometer, Thermometer, and Rain, at* Lyndon *in* Rutland; *by* Thomas Barker, *Eſq. Alſo of the Rain in* Hampſhire *and* Surrey. *Communicated by* Thomas White, *Eſq. F.R.S.*

Read April 30, 1789.

1788.

| | | Barometer. | | | Thermometer. | | | | | | Rain. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | In the Houſe. | | | Abroad. | | | Lyndon | Surrey. S. Lambeth. | Hampſhire. Selbourn. | Hampſhire. Fyfield. |
| | | Higheſt | Loweſt. | Mean. | High. | Low. | Mean | High. | Low. | Mean | | | | |
| | | Inches. | Inches. | Inches. | ° | ° | ° | ° | ° | ° | Inch. | Inch. | Inch. | Inch. |
| Jan. | Morn. | 30,13 | 28,37 | 29,50 | 44 | 34 | 40 | 45 | 23½ | 36 | 0,970 | 0,68 | 1,60 | 1,10 |
| | Aftern. | | | | 44 | 35 | 40½ | 49 | 30 | 41 | | | | |
| Feb. | Morn. | 29,77 | 28,25 | 29,14 | 45 | 35 | 40½ | 44 | 27½ | 36 | 2,667 | 2,09 | 3,37 | 2, 6 |
| | Aftern. | | | | 45 | 37 | 41 | 48 | 30 | 42 | | | | |
| Mar. | Morn. | 29,65 | 28,84 | 29,23 | 51 | 34 | 40 | 50 | 22 | 35 | 1,072 | 0,64 | 1,31 | 1,36 |
| | Aftern. | | | | 52½ | 35½ | 41 | 63 | 31 | 43 | | | | |
| Apr. | Morn. | 30,02 | 28,94 | 29,59 | 56 | 42½ | 50 | 54 | 35 | 45½ | 0,588 | 0,47 | 0,61 | 0,50 |
| | Aftern. | | | | 60 | 43½ | 51 | 68½ | 40 | 56 | | | | |
| May | Morn. | 29,92 | 29,19 | 29,60 | 68½ | 51 | 58 | 64 | 43½ | 52½ | 1,517 | 0,81 | 0,76 | 0,28 |
| | Aftern. | | | | 72 | 53 | 60 | 82 | 51 | 66 | | | | |
| June | Morn. | 29,85 | 29,10 | 29,52 | 65½ | 56 | 60 | 64½ | 50 | 56 | 0,608 | 1,94 | 1,27 | 1,36 |
| | Aftern. | | | | 69 | 57½ | 61 | 82½ | 58 | 67 | | | | |
| July | Morn. | 29,78 | 29,21 | 29,52 | 67½ | 58 | 62 | 70½ | 51 | 59 | 1,795 | 1,84 | 3,58 | 1,81 |
| | Aftern. | | | | 70 | 59½ | 63½ | 83 | 58 | 72 | | | | |
| Aug. | Morn. | 30,01 | 28,88 | 29,49 | 68 | 57½ | 61½ | 64 | 54 | 56 | 2,780 | 4,30 | 3,22 | 3,40 |
| | Aftern. | | | | 70½ | 59 | 63 | 77 | 62 | 68 | | | | |
| Sept. | Morn. | 29,80 | 29,00 | 29,40 | 66 | 52½ | 58½ | 61½ | 42 | 52 | 2,430 | 3,81 | 5,71 | 3,78 |
| | Aftern. | | | | 66½ | 53 | 59 | 75½ | 50 | 63 | | | | |
| Oct. | Morn. | 30,15 | 29,15 | 29,68 | 59 | 46 | 52 | 57 | 32 | 46 | 1,412 | 0,08 | 0, 0 | 0,03 |
| | Aftern. | | | | 60 | 47 | 53 | 66 | 45 | 54½ | | | | |
| Nov. | Morn. | 30,01 | 29,06 | 29,62 | 53 | 37 | 45 | 51½ | 25½ | 39 | 0,453 | 0,62 | 0,86 | 0,74 |
| | Aftern. | | | | 53 | 37½ | 46 | 58 | 31 | 45 | | | | |
| Dec. | Morn. | 29,85 | 29,12 | 29,47 | 39 | 27 | 34 | 40½ | 15 | 27 | 0,890 | 0,00 | 0,21 | 0,42 |
| | Aftern. | | | | 40½ | 28 | 34½ | 44½ | 22½ | 31½ | | | | |
| | | | | | | | | | | | Inches 17,182 | 17,28 | 22,50 | 16,84 |

THE

THE year began open and mild, at firſt ſhowery, afterward drier and ſtormy. The chief part of February was wet, but more ſo for frequency than quantity. After a few miſty days there came in March above a fortnight's ſharp froſt, the longeſt this winter, and with ſevere eaſt winds cut things more than all the winter before, which was in general an open one. The laſt twelve or thirteen days of March the ſpring ſet in pleaſant, and continued forwarding all April, and proved a very dry ſpring. There were at times this year fits of exceeding hot weather, the end of April, the fourth week in May, the third in June, and ſecond in July; but ſo much windy weather, with hot ſun and cold winds, that bees which were forward the beginning of May, and ſome few ſwarms ſo early, ſeemed backwarder again at the end of the month. The graſs was every where ſhort, and began to burn; but a fine rain at the end of May ſtrengthened the grain very much, and made the graſs grow in ſome degree; but it ſoon began to burn again in a dry June, with almoſt conſtant north and north-eaſt winds, ſo that the paſture was ſhort, and very little hay.

The end of June, and two-thirds of July, were very frequent ſhowers and wind. There were in ſome parts of England very heavy thunder-ſtorms, and more rain than they wiſhed for in hay-time. The ſhowers were light here; they made the grain ear well, peaſe and beans ſet thick, and brought the turnips paſt the fly. The graſs alſo grew in ſome degree, but burnt again before July was out, and more in Auguſt, of which the firſt ten days were dry; but the ſhowery latter part made the graſs grow conſiderably, which was much wanted, and did not much hinder the harveſt, which was in general well got, and was good. The autumn was very fine, and ſo much rain in one month, eſpecially the third week in September, that there

was more grass after that than there had been any part of the summer before, though not such quantities as there sometimes is; for, take the year throughout, I think I never knew less. But that was not the case in all parts of England: I believe it was in general a dry summer every where; but in some places there was a great deal of grass at times. So great a fruit year of most sorts, garden, orchard, and wild, I think, I hardly ever knew. After the first week in October it was dry again, and so fine, mild, and clear of frosts, that the nasturtiums were not cut off till after the middle of November; and the ground and roads continued dry till the snow at Christmas, and there was in many places great want of water so late in the year. Most part of the last week in November, and the first third part of December, was a gentle frost; but then it set in very severe, and, except an imperfect thaw the 24th and 25th, has been an uncommonly cold and hard frost, freezing over many of the rivers, with a considerable snow at times, chiefly the 26th and 27th, and continued to the end of the year, and beyond it.

*Account of a sinking-in of the ground.*

In a wet season, about Christmas 1787, a piece of apparently sound ground on the north side of a moderate hill, a mile and half south-west from Ketton in Rutland, sunk down into the earth, leaving a great hollow. The ground was smooth before, and a waggon had lately gone over the place. There was nobody by when it fell in; but a labourer going home from his work was the first person who found it.

It was some time after the accident before I heard of it, and

it

it was in ſpring time that I went to ſee it. I then found it to be an oval hole, five yards over one way, and four another, and about four yards deep in the middle; but ſome of the earth having lodged againſt the ſides of the pit, it was not ſo deep there; yet the oval muſt upon the whole have ſunk down about three yards, and gone directly downward, for the ſides of the pit are left perpendicular. I found a little water at the bottom of the pit, and was told there had been a great deal more at firſt. The bottom half of the pit is a blue clay, and from a foot to a yard thick at the top is a ſtiff earth mixed with ſtones. There were plain ſigns that a drain from the ground above had in wet times run down near where the pit now is; ſome of it probably ran into and under the ground, and had, in a courſe of time, undermined it; and that ſeems to have been the reaſon that the pit ſunk in as it has done.

A man of Ketton, who has freeſtone pits in the ſame lordſhip, but on the oppoſite ſide of the town, ſays, he ſometimes meets with beds of clay in his pits, which are undermined, and have hollows in them. And to the northward of theſe ſtone pits there are many hollows, which they call the Swallow-pits; becauſe, being hollow underneath, no water will lie in them, but runs through holes into the ground. Theſe ſwallow-pits I know, and they ſeem to be clay at top; and he ſays, they do not appear to have been ever dug by men, but that the ſurface of the ground has ſunk down into the hollow there was beneath it.

XVII. *On the Method of correſpondent Values*, &c. *By* Edward Waring, *M. D. F. R. S. and* Lucaſian *Profeſſor of the Mathematics at* Cambridge.

Read May 28, 1789.

1.

1. IN the year 1762 I publiſhed a method of finding when two roots of a given equation $x^n - px^{n-1} + qx^{n-2} - rx^{n-3} +$ &c. $= 0$ are equal, by finding the common diviſors of the two quantities $a^n - pa^{n-1} + qa^{n-2} -$ &c., and $na^{n-1} - \overline{n-1}pa^{n-2} + \overline{n-2}qa^{n-3} -$ &c., and obſerved if they admitted only one ſimple diviſor $(a - A)$, then two roots were only equal; if a quadratic $(a^2 - Aa + B)$, then two roots of the equation became twice equal; if a cubic $(a^3 - Aa^2 + Ba - C)$, then two roots became thrice equal; and ſo on: or, to expreſs in more general terms what follows from the ſame principles, if the common diviſor be $\overline{a-b}^r \times \overline{a-c}^t \times \overline{a-d}^v \times$ &c., then $r+1$ roots of the given equation will be $b$, $s+1$ roots will be $c$, $t+1$ will be $d$, &c.; and it immediately follows, from the principles delivered in the ſecond edition of the ſame Book, publiſhed in 1770, that to find when $r+1$, $v+1$, $t+1$, &c. roots are reſpectively equal requires $r+s+t$, &c. equations of condition, which are deducible from the well known method of finding the common diviſors of two quantities in this caſe of $a^n - pa^{n-1} + qa^{n-2} -$ &c., $na^{n-1} - \overline{n-1}pa^{n-2} + \overline{n-2}qa^{n-3} -$ &c. of the terms of their remainders, &c.

In

In the book above mentioned the equations of condition are given, which discover when two roots are equal in the equations $x^4 - px^3 + qx - r = 0$, $x^5 + qx^3 - rx + s = 0$, $x^5 + qx^2 - rx^2 + sx - t = 0$, in the two latter equations the second term is wanting, which may easily be exterminated; but it may as easily be restored by substituting for $q$, $r$, $s$, &c. in the equation of condition found the quantities resulting from the common transformation of equations to destroy the second term.

2. Another rule contained in the same Book is the substitution of the roots of the equation $na^{n-1} - \overline{n-1}pa^{n-2} + \overline{n-2}qa^{n-3} - \&c. = 0$ respectively for $a$ in the quantity $a^n - pa^{n-1} + qa^{n-2} - \&c.$, and multiplication of all the quantities resulting into each other; their content will give the equation of condition, when two roots are equal.

Mr. HUDDE first discovered, that if the successive terms of the given equation are multiplied into an arithmetical series, the resulting equation will contain one of any two equal roots, and $m$ of the $\overline{m+1}$ equal roots in the given equation.

3. If 3, 4, 5, . . $r$ roots of the equation are equal, find a common divisor of 3, 4, 5, . . $r$ of the subsequent quantities $a^n - pa^{n-1} + qa^{n-2} - \&c.$, $na^{n-1} - \overline{n-1}pa^{n-2} + \overline{n-2}qa^{n-3} - \&c.$, $n \cdot \overline{n-1}a^{n-2} - \overline{n-1} \cdot \overline{n-2}pa^{n-3} + \overline{n-2} \cdot \overline{n-3}qa^{n-4} - \overline{n-3} \cdot \overline{n-4}ra^{n-5} + \&c.$, $n \cdot \overline{n-1} \cdot \overline{n-2}a^{n-3} - \overline{n-1} \cdot \overline{n-2} \cdot \overline{n-3}pa^{n-4} + \overline{n-2} \cdot \overline{n-3} \cdot \overline{n-4}qa^{n-5} - \&c.$, . . . $n \cdot \overline{n-1} \cdot \overline{n-2} \cdot \overline{n-r+2}a^{n-r+1} - \overline{n-1} \cdot \overline{n-2} \cdot \overline{n-r+1}pa^{n-r} + \&c.$; which will probably be best done by dividing all the preceding quantities by the quantity of the least dimension of $a$, and the divisor and all the remainders by that quantity which has the least dimensions amongst them; and so on: there will result 2, 3, 4, . . $r-1$ equations of condition; and in this case it is

obſerved, in the before-mentioned Book, that (if the common diviſor be $(a - A)$) it will once only admit of 3, 4, 5, .. $r$ equal roots; if it be a quadratic, then it will twice admit of thoſe equal roots; and ſo on.

4. If the roots of the equation of the leaſt dimenſions be ſubſtituted for $a$ in the remaining equations, and each of the reſulting values of the ſame equation be multiplied into each other, there will reſult the $r - 1$ equations of condition: and the ſame may be deduced alſo from the ſeveral equations conjointly.

The equations of conditions found by the firſt method, if the diviſions were not properly inſtituted, may admit of more rational diviſors than neceſſary, of which ſome are the equations of conditions required.

2.

1. In the year 1776, I publiſhed in the Meditationes Analyticæ a new method of differences for the reſolution of the following problem.

Given the ſums of a ſwiftly converging ſeries $ax + bx^2 + cx^3 + dx^4 +$ &c., when the values of $x$ are reſpectively $\pi, \rho, \varsigma,$ &c.; to find the ſum of the ſeries when $x$ is $\tau$, that is, given $S\pi = a\pi + b\pi^2 + c\pi^3 + d\pi^4 +$ &c., $S\rho = a\rho + b\rho^2 + c\rho^2 +$ &c., $S\sigma = a\sigma + b\sigma^2 + c\sigma^3 +$ &c. &c.; to find $S\tau = a\tau + b\tau^2 + c\tau^3 +$ &c.

To reſolve this problem I multiplied the quantities, $S\pi$, $S\rho$, $S\sigma$, &c. reſpectively into unknown co-efficients $\alpha, \beta, \gamma,$ &c. and there reſulted

$\alpha\pi$

$$\alpha\pi a + \alpha\pi^2 b + \alpha\pi^3 c + \&c.$$
$$\beta\rho a + \beta\rho^2 b + \beta\rho^3 c + \&c.$$
$$\gamma\sigma a + \gamma\sigma^2 b + \gamma\sigma^3 c + \&c.$$
$$\&c. \quad \&c. \quad \&c.$$

and then made the ſum of each of the terms reſpectively equal to its correſpondent term of the quantity $\tau a + \tau^2 b + \tau^3 c + \&c.$, and conſequently $\alpha\pi + \beta\rho + \gamma\sigma + \&c. = \tau$, $\alpha\pi^2 + \beta\rho^2 + \gamma\sigma^2 + \&c. = \tau^2$, $\alpha\pi^3 + \beta\rho^3 + \gamma\sigma^3 + \&c. = \tau^3$, &c. I aſſumed as many equations of this kind as there were given values $\pi$, $\rho$, $\sigma$, &c. of $x$; and conſequently as many equations reſulted as unknown quantities $\alpha$, $\beta$, $\gamma$, &c.; whence, by the common reſolution of ſimple equations, or more eaſily from differences, can be found the unknown quantities $\alpha$, $\beta$, $\gamma$, &c., and thence the equation ſought $\alpha \times S\pi + \beta \times S\rho + \gamma \times S\sigma + \&c. = S\tau$ nearly.

3. In the Meditationes are aſſumed for $\pi$, $\rho$, $\sigma$, &c. the quantities $p$, $2p$, $3p$, $4p$, $\ldots \overline{n-2}p$, $\overline{n-1}p$, and $np$ for $\tau$; which, if ſubſtituted for their values in the preceding equations, will give $\alpha + 2\beta + 3\gamma + 4\delta + \&c. = n$, $\alpha + 4\beta + 9\gamma + 16\delta + \&c. = n^2$, $\alpha + 8\beta + 27\gamma + \&c. = n^3$, $\alpha + 16\beta + 81\gamma + \&c. = n^4$; and if the ſums of the ſeries $ax + bx^2 + cx^3 + \&c.$ which reſpectively correſpond to the values $p$, $2p$, $3p$, $\ldots \overline{n-1}p$ of $x$ be $S1$, $S2$, $S3$, $S4$, $\ldots S\overline{n-1}$, and the ſum of the ſeries $ax + bx^2 + cx^3 + \&c.$ which correſponds to $n$ value of $x$ be $Sn$; then will $Sn = nS\overline{n-1} - n \cdot \frac{n-1}{2} S\overline{n-2} + n \cdot \frac{n-1}{2} \cdot \frac{n-2}{2} S\overline{n-3} \ldots \pm nS1$ nearly, which equation is given in the above-mentioned Book.

3. The logarithm from the number, the arc from the ſine, &c. are found by ſerieſes of the formula $ax + bx^2 + cx^3 + \&c.$; and conſequently this equation is applicable to them.

4. In the ſame Book is aſſumed a ſeries $ax^r + bx^{r+s} + cx^{r+2s} + dx^{r+3s}$ + &c. of a more general formula than the preceding, and in it for $x$ ſubſtituted $\alpha$, $\beta$, $\gamma$, $\delta$, &c., $m$; and $S\alpha$, $S\beta$, $S\gamma$, $S\delta$, &c; $Sm$ for the reſulting ſums, and thence deduced

$$Sm = \frac{m^r \times \overline{m^s - \beta^s} \cdot \overline{m^s - \gamma^s} \cdot \overline{m^s - \delta^s} \cdot \&c.}{\alpha^r \times \overline{\alpha^s - \beta^s} \cdot \overline{\alpha^s - \gamma^s} \cdot \overline{\alpha^s - \delta^s} \cdot \&c.} \times S\alpha + \frac{m^r \times \overline{m^s - \alpha^s} \cdot \overline{m^s - \gamma^s} \cdot \overline{m^s - \delta^s} \cdot \&c.}{\beta^r \times \overline{\beta^s - \alpha^s} \cdot \overline{\beta^s - \gamma^s} \cdot \overline{\beta^s - \delta^s} \cdot \&c.}$$

$$\times S\beta + \frac{m^r \times \overline{m^s - \alpha^s} \cdot \overline{m^s - \beta^s} \cdot \overline{m^s - \delta^s} \cdot \&c.}{\gamma^r \times \overline{\gamma^s - \alpha^s} \cdot \overline{\gamma^s - \beta^s} \cdot \overline{\gamma^s - \delta^s} \cdot \&c.} \times S\gamma + \frac{m^r \times \overline{m^s - \alpha^s} \cdot \overline{m^s - \beta^s} \cdot \overline{m^s - \gamma^s} \times \&c.}{\delta^r \times \overline{\delta^s - \alpha^s} \cdot \overline{\delta^s - \beta^s} \cdot \overline{\delta^s - \gamma^s} \cdot \&c.}$$

$\times S\delta$ + &c. nearly.

*Cor.* If for $r$ and $s$ be aſſumed reſpectively 1, the ſeries becomes $ax + bx^2 + cx^3$ + &c. of the ſame formula as the preceding: if $r = 0$ and $s = 1$, the ſeries becomes $a + bx + cx^2$ + &c. The latter caſe will be the ſame as the former, when one of the quantities ($\alpha$) ſubſtituted for $x$ and its correſpondent ſum $S\alpha$, both become $= 0$, and the equation deduced in both caſes the ſame.

5. If $\pi$, $\rho$, $\sigma$, &c. reſpectively denote $r$, $r + p$, $r + 2p$, ... $r + \overline{n - 2}p$, $r + \overline{n - 1}p$, and $\tau = r + np$; and S, S1, S2, S3, ..., $S\overline{n - 2}$, $S\overline{n - 1}$, be the ſums either reſulting from the ſeries $ax + bx^2 + cx^3$ + &c. or the ſeries $A + ax + bx^2 + cx^3$ + &c., which reſpectively correſpond to the values $r$, $r + p$, $r + 2p$, &c. of $x$; and $Sn$ the ſum of the ſame ſeries which correſponds to the value $r + np$ of $x$; then will $Sn = nS\overline{n - 1} - n \cdot \frac{n-1}{2} S\overline{n - 2} + n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} S\overline{n - 3} - \ldots \pm n \cdot \frac{n-1}{2} S2 \mp nS1 \pm S$ nearly; this equation differs from the preceding by the laſt term S not vaniſhing; in the preceding caſe S became $= 0$, for it was the ſum of the ſeries $ax + bx^2 + cx^3$ + &c., which correſponded to $x = 0$.

6. From

6. From the Meditationes it appears, that $r^m - n \times \overline{r \pm p}^m + n \cdot \frac{n-1}{2} \overline{r \pm 2p}^m - n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \overline{r \pm 3p}^m$ + &c. to the end of the ſeries = 0, if $m$ is leſs than $n$, and $m$ and $n$ are whole numbers; but if $m = n$, then it will $= \pm 1 \cdot 2 \cdot 3 \cdot 4 \ldots \overline{n-1} \cdot np^n$; whence it is manifeſt, that for the $n$ firſt terms of the ſeries $A + ax + bx^2$ + &c. the equations are true; and for the $n-1$ firſt terms of the ſeries $ax + bx^2 + cx^3$ + &c. and in the ſucceſſive term of both the ſerieſes they will err by a quantity nearly $= \pm 1 \cdot 2 \cdot 3 \ldots n \times p^n \times r^{-n} \times$ co-efficient of the term; and the errors of every ſubſequent term $(x^{b+n})$ will be nearly as $\pm m \cdot \frac{\overline{m-1}}{2} \cdot \frac{\overline{m-2}}{3} \cdot \frac{\overline{m-3}}{4} \ldots \frac{\overline{m-b+1}}{b} \times p^n \times r^{-n} \times$ co-efficient of the term $x^{b+n}$, if for $r$, $r+p$, $r+2p$, &c. be ſubſtituted $1$, $1+\frac{p}{r}$, $1+\frac{2p}{r}$, &c.

7. Let the preceding equation $Sn = nS\overline{n-1} - n \cdot \frac{n-1}{2} S\overline{n-2} + n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \cdot S\overline{n-3}$ – &c. $= n \times \log. \overline{r-p} - n \cdot \frac{n-1}{2} \log. \overline{r-2p} + n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \log. \overline{r-3p}$ + &c. $= \log. \frac{r \times \overline{r-2p}^s \times \overline{r-4p}^{s'} \times \overline{r-6p}^{s''} \times \&c.}{\overline{r-p}^t \times \overline{r-3p}^{t'} \times \overline{r-5p}^{t''} \times \&c.} = \log. K$, where $s$, $s'$, $s''$, &c. denote the co-efficients of the alternate terms of the binomial theorem, *viz.* $s = n \cdot \frac{n-1}{2}$, $s' = n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \cdot \frac{n-3}{4}$, &c., and $t = n$, $t' = n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3}$, &c. the co-efficients of the remaining alternate terms; the numerator $r \times \overline{r-2p}^s \times \overline{r-4p}^{s'} \times \overline{r-6p}^{s''} \times \&c. = (\text{if } N = 2^{n-1})\ r^N - Pp r^{N-1} + Qp^2 r^{N-2} - Rp^3 r^{N-3} \ldots L p^{n-1} \times r^{N-n+1} \pm M p^n r^{N-n} \pm \&c.$; and the denominator $\overline{r-p}^t \times \overline{r-3p}^{t'} \times \overline{r-5p}^{t''} \times \&c. = r^N - Pp r^{N-1} + Qp^2 r^{N-2} -$

$R p^3 r^{N-3} + \ldots L p^{n-1} r^{N-n+1} (\pm M + 1 \cdot 2 \cdot 3 \ldots \overline{n-1}) p^n r^{N-n} =$ &c., whence the numerator and denominator have the $n$ firſt terms the ſame, and the next ſucceeding terms differ by $1 \cdot 2 \cdot 3 \ldots \overline{n-1} p^n r^{N-n}$; the numerator divided by the denominator $= 1 \pm \frac{1 \cdot 2 \cdot 3 \ldots \overline{n-1}}{r^n} p^n$ nearly, if $r$ be a great number in proportion to $p$, &c. it would be + when $n$ is an odd number, and − when even.

8. The logarithm of the fraction K by the common ſeries $= K - 1 - \frac{\overline{K-1}^2}{2} + \frac{\overline{K-1}^3}{3} -$ &c. has for its firſt term $= \pm \frac{1 \cdot 2 \cdot 3 \ldots \overline{n-1}}{r^n} \times p^n$ nearly; for its ſecond term the ſquare of the firſt divided by 2, &c.

9. The error of this equation not only depends on the logarithm of K, which may be calculated to any degree of exactneſs, but in the calculus on the errors of the given logarithms.

10. If $r$ be increaſed or diminiſhed by any given number, the $n$ firſt terms of the numerator and denominator will ſtill reſult the ſame, and the next ſucceeding terms will differ by $1 \cdot 2 \cdot 3 \cdot 4 \ldots n-1 \times p^n \times r^{N-n}$.

11. Let $n \cdot \frac{n-1}{2}$ numbers be 2, $n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \cdot \frac{n-3}{4}$ numbers be 4, $n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \cdot \frac{n-3}{4} \cdot \frac{n-4}{5} \cdot \frac{n-5}{6}$ numbers be 6, &c.; their ſum, the ſum of the products of every two, the contents of every three, four, five, &c. to $n-1$ of them will be equal to the ſum, the ſum of the products of every two, of the contents of every three, four, five, &c. to $\overline{n-1}$ of the following numbers, *viz.* $n$ numbers which are 1, $n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3}$ numbers

numbers which are $3, n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} \cdot \frac{n-3}{4} \cdot \frac{n-4}{5}$, which are 5, &c.; and the ſum of the contents of every $n$ of the former will be leſs than the ſum of the contents of every $n$ latter numbers by $1 \cdot 2 \cdot 3 \cdot 4 \ldots \overline{n-1}$.

12. The method given in Art. 4. which I name a method of correſpondent values, eaſily deduces and demonſtrates the preceding equations, which cannot, without much difficulty, be done by the preceding method of differences; the method of correſpondent values is much preferable to the method of differences, both for the facility of its deduction, and the generality of its reſolution: for inſtance, from this method very eaſily can be deduced, &c. the ſubſequent and other ſimilar equations.

Ex. 1. $Sn = nS\overline{n-1} - n \cdot \frac{n-1}{2} S\overline{n-2} + n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} S\overline{n-3} \ldots = nS1 = S$ nearly.

Ex. 2. $S\overline{n+m} = \frac{\overline{m+n} \cdot \overline{m+n-1} \cdot \overline{m+n-2} \ldots \overline{m+2}}{1 \cdot 3 \ldots \overline{n-1}} \times S\overline{n-1} - \frac{n-1}{1} \times A \times \frac{m+1}{m+2} \times S\overline{n-2} + \frac{n-2}{2} \times B \times \frac{m+2}{m+3} S\overline{n-3} - \frac{n-3}{3} \times C \times \frac{m+3}{m+4} \times S\overline{n-4} + \frac{n-4}{4} \times D \times \frac{m+4}{m+5} \times S\overline{n-5}$ – &c. nearly, where the letters A, B, C, D, &c. denote the preceding co-efficients, and the converging ſeries is the ſame as in the preceding example.

Ex. 3. Let the converging ſeries be of the formula $ax + bx^3 + cx^5 + dx^7 +$ &c.; then will $Sn = \overline{2n-2} S\overline{n-1} - \overline{2n-1} \times \frac{2n-4}{2} S\overline{n-2} + \overline{2n-1} \times \frac{2n-2}{2} \times \frac{2n-6}{3} S\overline{n-3} - \overline{2n-1} \cdot \frac{2n-2}{2} \cdot \frac{2n-8}{4} S\overline{n-4} +$ &c. nearly, of which the general term is $\overline{2n-1} \cdot \frac{2n-2}{2} \cdot \frac{2n-3}{3} \cdot \ldots \frac{2n-l+1}{l-1} \times \frac{2n-2l}{l} \times S\overline{n-l}$.

Ex. 4. Let the series be of the formula $A + ax^{\frac{1}{2}} + bx^{\frac{2}{2}} + cx^{\frac{3}{2}} +$ &c.; then will $Sn = \frac{n-1}{n} \times \overline{2n-2}\, Sn-1 - \frac{n-2}{n} \times \overline{2n-1} \cdot \frac{2n-4}{2} \times \overline{Sn-2} + \frac{n-3}{n} \times \overline{2n-1} \cdot \frac{2n-2}{2} \cdot \frac{2n-6}{3} \overline{Sn-3} - \frac{n-4}{n} \times \overline{2n-1} \cdot \frac{2n-2}{2} \cdot \frac{2n-3}{3} \times \frac{2n-8}{4} \overline{Sn-4} +$ &c. nearly, of which the general term is $\frac{n-l}{n} \times \overline{2n-1} \cdot \frac{2n-2}{3} \cdot \frac{2n-3}{3} \cdots \frac{2n-l+1}{l-1} \times \frac{2n-2l}{l} \times \overline{Sn-L}$.

Ex. 5. Let the given series be of the formula $ax + bx^2 + cx^3$ + &c., and in it for $x$ be substituted $p$, $-p$, $2p$, $-2p$, $3p$, $-3p$, . . . , $np$, $-np$ and $mp$, and for the sums of the resulting series be wrote respectively $S^1$, $S^{-1}$, $S^2$, $S^{-2}$, $S^3$, $S^{-3}$, . . . $S^n$, $S^{-n}$, and $Sm$; then will $Sm = \frac{\overline{m \cdot m^2-1 \cdot m^2-4 \cdot m^2-9 \cdot m^2-16 \cdots m^2-n-1^2} \cdot \overline{m-n}}{\overline{p \cdot p^2-1 \cdot p^2-4 \cdot p^2-9 \cdot p^2-16 \cdots p^2-n-1^2} \times 2n = 1 \cdot 2 \cdot 3 \cdot 4 \cdots 2n} \times S^{-n} + A \times \frac{m+n}{m-n} S^{+n} - \frac{2n}{1} \times B \times \frac{m-n}{m+n-1} S^{-n+1} - C \times \frac{m+n-1}{m-n-1} \times S^{n-1} + \frac{2n-1}{2} \times D \times \frac{m-n-1}{m+n-2} \times S^{-n+2} + \frac{m+n-2}{m-n-2} \times E\, S^{n-2} - \frac{2n-2}{3} \times F \times \frac{m-n-2}{m+n-3} S^{-n+3} - G \times \frac{m+n-3}{m-n-3} \times S^{n-3} +$ &c. nearly, where the letters A, B, C, D, &c. respectively denote the preceding co-efficients. In general, the co-efficients of the terms $S^{-n+s}$ and $S^{n-s}$ will be respectively $M = \frac{2n-s+1}{s} \times L \times \frac{m-n-s+1}{m+n-s}$ and $M \times \frac{m+n-s}{m-n-s}$, where the letters L and M respectively denote their preceding co-efficients; the co-efficients are to be taken affirmatively, or negatively, according as $s$ is an even or odd number.

Ex. 6. If for $x$ in the preceding series be substituted $p$, $-p$, $2p$, $-2p$, $3p$, $-3p$, . . . $\overline{n-1}p$, $-\overline{n-1}p$, $np$ respectively, then

Sm

$Sm = \frac{m \cdot \overline{m^2-1} \cdot \overline{m^2-4} \cdot \overline{m^2-9} \cdot \overline{m^2-16} \ldots \overline{m^2-(n-1)^2}}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \ldots (2n-1)} S^s - A \times \frac{m-n}{m+n-1} \times S^{-s+1} - \frac{2n-1}{1} \times B \times \frac{m+n-1}{m-n-1} \times S^{s-1} + C \times \frac{m-n-1}{m+n-2} \times S^{-s+2} + \frac{2n-2}{2} \times D \times \frac{m+n-2}{m-n-2} \times S^{s-2}$ – &c. nearly, when A, B, C, &c. denote as before the preceding co-efficients. The coefficients of the terms $S^{-s+1}$ and $S^{s-1}$ will be reſpectively $L \times \frac{m-n-s+1}{m+n-s}$ and $\frac{2n-1}{1} \times M \times \frac{m+n-s}{m-n-s}$, L and M denoting the preceding co-efficients, which are to be taken negatively or affirmatively, as $s$ is an even or an odd number. In this ſeries when $x = 0$, the correſpondent ſum $= 0$.

Ex. 7. Let the given ſeries be of the formula $a + bx + cx^2 + dx^3 +$ &c.; and in it for $x$ be ſubſtituted $o$, $p$, $-p$, $2p$, $-2p$, $3p$, $-3p \ldots np$, $-pp$ and $mp$, and for the ſums of the reſulting ſerieſes be wrote as before $S^o$, $S^1$, $S^{-1}$, $S^2$, $S^{-2}$, $\ldots S^s$, $S^{-s}$, and $S^m$; then will $Sm = \frac{m \cdot \overline{m^2-1} \cdot \overline{m^2-4} \cdot \overline{m^2-9} \ldots \overline{(m^2-n-1^2)} \times \overline{m-n}}{n \cdot \overline{n^2-1} \cdot \overline{n^2-4} \cdot \overline{n^2-9} \ldots \overline{(n^2-n-1^2)} \times 2n} \times S^{-n} + A \times \frac{m+n}{m-n} \times S^{+n} - \frac{2n}{1} \times B \times \frac{m-n}{m+n-1} S^{-n+1}$ – &c. this ſeries obſerves the ſame law as the ſeries given in Ex. 5. and only differs from it by the laſt term $So$ not vaniſhing, that is, being $= o$.

Ex. 8. Let the ſeries be of the preceding formula $a + bx + cx^2 + dx^3 +$ &c., and in it for $x$ be ſubſtituted $o$; $p$, $-p$; $2p$, $-2p$; $3p$, $-3p$; $\ldots \overline{n-1}p$, $-\overline{n-1}p$, $np$, and $mp$, and the ſums reſulting be $So$, $S1$, $S^{-1}$, $S^2$, $S^{-2}$, $\ldots S^{n-1}$, $S^{-n+1}$, $S^n$ and $S^m$; then will $Sm = \frac{m \cdot \overline{m^2-1} \cdot \overline{m^2-4} \ldots \overline{m^2-(n-1)^2}}{1 \cdot 2 \cdot 3 \cdot 4 \ldots 2n-1} S^n - A \times \frac{m-n}{m+n-1} \times S^{-n+1}$ – &c. the ſame ſeries as in Ex. 6. and differs from it only by the laſt term $So$ not vaniſhing.

Ex. 9. Let the ſeries be of the ſame formula $a+bx+cx^2+dx^3+$ &c. and in it for $x$ be ſubſtituted $p$, $-p$, $3p$, $-3p$, $5p$, $-5p$, $7p$, $-7p$, .... $np$, $-np$ and $mp$; and the ſums reſulting be $S^1$, $S^{-1}$, $S^3$, $S^{-3}$, $S^5$, $S^{-5}$, $S^7$, $S^{-7}$, .... $S^n$, $S^{-n}$, and $S^m$; then will $S^m = \frac{m^2-1 \cdot m^2-9 \cdot m^2-25 \cdot m^2-49 \ldots m^2-n-2}{n^2-1 \cdot n^2-9 \cdot n^2-25 \cdot n^2-49 \ldots n^2-n-2} \times \frac{m+n}{2^n \times 1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \ldots n} \times S^n - A \times \frac{m-n}{m+n} \times S^{-n} - \frac{n}{1} \times B \times \frac{m+n}{m-n+2} \times S^{-n+2} + C \times \frac{m-n+2}{m+n-2} \times S^{-n+4} + \frac{n-1}{2} \times D \times \frac{m+n-2}{m-n+4} \times S^{-n+6} - E \times \frac{m-n+4}{m+n-4} S^{-n+8} - \frac{n-2}{3} F \times \frac{m+n-4}{m-n+6} S^{-n+10} + \frac{m-n+6}{m+n-6} \times G \times S^{-n+12} + \frac{n-3}{4} \times H \times \frac{m+n-6}{m-n+8} \times S^{-n+14} -$ &c. nearly, where the letters A, B, C, D, E, &c. denote the preceding co-efficients of the terms $S^n$, $S^{-n}$, $S^{-n+2}$, $S^{-n+4}$, $S^{-n+6}$, $S^{-n+8}$, &c. reſpectively. The co-efficients of the terms $S^{2s-2i}$ and $S^{-n+2i}$ will be $M = \frac{n-i+1}{i} \times L \times \frac{m+n-2i+2}{m-n+2i}$ and $N = M \times \frac{m-n+2i}{m+n-2i}$; where L, M, and N denote the co-efficients of the terms immediately preceding each other, that is, of the terms $S^{-n+2i-4}$, $S^{-n+2i}$, and $S^{-n+2i+2}$. The ſign of the firſt co-efficient M will be + or −, according as $i$ is even or odd; the ſecond term N will have a contrary ſign to the firſt.

Theſe ſeries may be made to begin from any term, which may be eaſily found by the method of correſpondent values, and the ſubſequent terms from it by the given law; its preceding terms may be deduced from the ſame law reverſed, that is, by putting the numerators of the fractions multiplied into it for the denominators, and the denominators for the numerators.

From theſe different ſerieſes may be formed, by adding two or more terms of the given ſeries together for a term of the required ſeries; which method has been applied to converging ſeries in general in the Meditationes.

13. The method of correſpondent values eaſily affords a reſolution of the problems contained in Mr. Brigg's or Sir Isaac Newton's method of differences.

Ex. 1. Let the quantity be of the formula $a+bx+cx^2+dx^3+\&c.\ldots x^n=y$, and $n+1$ correſpondent values of $x$ and $y$ be given, *viz.* $p$, $q$, $r$, $s$, &c. of $x$; $Sp$, $Sq$, $Sr$, $Ss$, &c. of $y$; then will $y=\frac{\overline{x-q}\cdot\overline{x-r}\cdot\overline{x-s}\cdot\&c.}{\overline{p-q}\cdot\overline{p-r}\cdot\overline{p-s}\cdot\&c.}\times Sp+\frac{\overline{x-p}\cdot\overline{x-r}\cdot\overline{x-s}\cdot\&c.}{\overline{q-p}\cdot\overline{q-r}\cdot\overline{q-s}\cdot\&c.}\times Sq+\frac{\overline{x-p}\cdot\overline{x-q}\cdot\overline{x-s}\cdot\&c.}{\overline{r-p}\cdot\overline{r-q}\cdot\overline{r-s}\cdot\&c.}\times Sr+\frac{\overline{x-p}\cdot\overline{x-q}\cdot\overline{x-r}\cdot\&c.}{\overline{s-p}\cdot\overline{s-q}\cdot\overline{s-r}\cdot\&c.}\times Ss+\&c.$

The truth of this problem very eaſily appears by writing $p$, $q$, $r$, $s$, &c. for $x$ in the given ſeries.

All the preceding examples may be applied to this caſe, by writing $x$ for $m$ in the given ſeries; hence the reſolutions of ſeveral caſes of equi-diſtant ordinates by eaſy and not inelegant ſerieſes, amongſt which are included the two caſes commonly given on this ſubject.

14. If a quantity be required, which proceeds according to the dimenſions of $x$, reduce the above given value of $y$ into a quantity proceeding according to the dimenſions of $x$, and there reſults $y=\Big(\underbrace{\frac{Sp}{\overline{p-q}\cdot\overline{p-r}\cdot\overline{p-s}\cdot\&c.}}_{=A}+\underbrace{\frac{Sq}{\overline{q-p}\cdot\overline{q-r}\cdot\overline{q-s}\cdot\&c.}}_{=B}+\underbrace{\frac{Sr}{\overline{r-p}\cdot\overline{r-q}\cdot\overline{r-s}\cdot\&c.}}_{=C}+\underbrace{\frac{Ss}{\overline{s-p}\cdot\overline{s-q}\cdot\overline{s-r}\cdot\&c.}}_{=D}+\&c.\Big)\times x^n-\Big(\underbrace{\frac{Sp\times\overline{q+r+s+\&c.}}{A}}+\underbrace{\frac{Sq\times\overline{p+r+s+\&c.}}{B}}+\underbrace{\frac{Sr\times\overline{p+q+s+\&c.}}{C}}+\underbrace{\frac{Ss\times\overline{p+q+r+\&c.}}{D}}+\&c.\Big)x^{n-1}+\Big(\underbrace{\frac{Sp\times\overline{qr+qs+rs+\&c.}}{A}}+$

Sq

$$\frac{Sq\times\overline{p^2+ps+rs+\&c.}}{B}+\frac{Sr\times\overline{p^2+pr+q^2+\&c.}}{C}+\frac{Ss\times\overline{pq+pr+qr+\&c.}}{D}+\&c.)$$
$$\times x^{n-2}-\Big(\frac{Sp\times\overline{qrs+\&c.}}{A}+\frac{Sq\times\overline{pr^2+\&c.}}{B}+\frac{Sr\times\overline{pqs+\&c.}}{C}+\frac{Ss\times\overline{pqr+\&c.}}{D}+$$
$\&c.)\,x^{n-3}+\&c.$

The law and continuation of this series is evident to any one versant in these matters from inspection.

These fractions may be reduced to a common denominator by substituting for $Sp$ and A the products $Sp\times P$ and $A\times P$, where $P=\overline{q-r}\,.\,\overline{q-s}\,.\,\overline{r-s}\,.\,\&c.$; for $Sq$ and B the products $Sq\times Q$ and $B\times Q$, where $Q=\overline{p-r}\,.\,\overline{p-s}\,.\,\overline{r-s}\,.\,\&c.$; for $Sr$ and C the products $Sr\times R$ and $C\times R$, where $R=\overline{p-q}\,.\,\overline{p-s}\,.\,\overline{q-s}\,.$ &c.; for $Ss$ and D the products $Ss\times S'$ and $C\times S'$, where $S'=\overline{p-q}\,.\,\overline{p-r}\,.\,\overline{q-r}\,.\,\&c.\,\&c.$

The fractions, in particular cases, will often be reducible to lower terms.

15. Let $y=ax^b+bx^{b+i}+cx^{b+2i}+\&c.$, and the correspondent values of $x$ and $y$ be given as before, then will $y=$
$$\frac{x^b\times\overline{x^i-q^i}\times\overline{x^i-r^i}\times\overline{x^i-s^i}\times\&c.}{p^b\times\overline{p^i-q^i}\times\overline{p^i-r^i}\times\overline{p^i-s^i}\times\&c.}\times Sp+\frac{x^b\times\overline{x^i-p^i}\times\overline{x^i-r^i}\times\overline{x^i-s^i}\times\&c.}{q^b\times\overline{q^i-p^i}\times\overline{q^i-r^i}-q-s\times\&c.}\times Sq$$
$$+\frac{x^b\times\overline{x^i-p^i}\times\overline{x^i-q^i}\times\overline{x^i-s^i}\times\&c.}{r^b\times\overline{r^i-p^i}\times\overline{r^i-q^i}\times\overline{r^i-s^i}\times\&c.}\times Sr+\frac{x^b\times\overline{x^i-p^i}\times\overline{x^i-q^i}\times\overline{x^i-r^i}\times\&c.}{s^b\times\overline{s^i-p^i}\times\overline{s^i-q^i}\times\overline{s^i-r^i}+\&c.}\times$$
$Ss+\&c.$

This series may in the same manner as the preceding be reduced to terms, proceeding according to the dimensions of $x$; and the series given in the examples may *(mutatis mutandis)* be predicated of it.

16. A more general method of correspondent values is given in the Meditationes, as also the subsequent $y=\frac{\overline{x-q}\,.\,\overline{x-r}\,.\,\overline{x-s}\,.\,\&c.}{\overline{p-q}\,.\,\overline{p-r}\,.\,\overline{p-s}\,.\,\&c.}\times$

$\times Sp + \frac{x-p \cdot x-r \cdot x-s \cdot \&c.}{q-p \cdot q-r \cdot q-s \cdot \&c.} \times Sq + \frac{x-p \cdot x-q \cdot x-s \cdot \&c.}{r-p \cdot r-q \cdot r-s \cdot \&c.} \times Sr +$

&c. as in Ex. 1. $= Sp + (x-p)\left(\frac{1}{p-q} \times Sp + \frac{1}{q-p} \times Sq\right) + (x-p)(x-q)\left(\frac{1}{p-q} \times \frac{1}{p-r} \times Sp + \frac{1}{q-p} \times \frac{1}{q-r} \times Sq + \frac{1}{r-p} \times \frac{1}{r-q} \times Sr\right) + (x-p)(x-q)(x-r)\left(\frac{1}{p-q} \cdot \frac{1}{p-r} \cdot \frac{1}{p-s} \times Sp + \frac{1}{q-p} \cdot \frac{1}{q-r} \cdot \frac{1}{q-s} \times Sq + \frac{1}{r-p} \cdot \frac{1}{r-q} \cdot \frac{1}{r-s} \times Sr + \frac{1}{s-p} \cdot \frac{1}{s-q} \cdot \frac{1}{s-r} \times Ss\right) - \&c.$

The equality of theſe two different quantities will eaſily appear by finding the co-efficients of both, which are multiplied into the ſame given value of $y$ as $Sp$, $Sq$, $Sr$, &c. and the ſame power of $x$; for with very little difficulty they will in general be found equal.

It is evident from this reſolution that, giving the ordinates and their reſpective diſtances from each other, the value of any other ordinate at a given diſtance from the preceding, found by this method, will reſult the ſame, whatever may be the point aſſumed from which the abſciſs is made to begin.

## 3.

1. Let a ſeries be $Ax + Bx^2 + Cx^3 + Dx^4 + \&c.$ of ſuch a formula that if in it for $x$ be ſubſtituted $a+b$, there reſults a ſeries $A \times \overline{a+b} + B \times \overline{a+b}^2 + C \times \overline{a+b}^3 + D \times \overline{a+b}^4 + \&c. = (Aa + Ba^2 + Ca^3 + Da^4 + \&c.) \times (1 + qb + rb^2 + sb^3 + tb^4 + \&c.) + (1 + qa + ra^2 + sa^3 + ta^4 + \&c.) \times (Ab + Bb^2 + Cb^3 + Db^4 + \&c.)$ then will the ſeries $Ax + Bx^2 + Cx^3 + Dx^4 + \&c. = Ax + \frac{2B}{1 \cdot 2}x^2 + \frac{2 \cdot 3C}{1 \cdot 2 \cdot 3}x^3 + \frac{24ABC - 8B^3}{1 \cdot 2 \cdot 3 \cdot 4A^2}x^4 + \frac{36C^2A^2 + 24ACB^2 - 16B^4}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5A^3}x^5 + \frac{9 \cdot 24A^2BC^2 - 4 \times 24AB^3C}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \cdot 6A^4}x^6 + \frac{216C^3A^3 + 432A^2B^2C^2 - 384ACB^4 + 64B^6}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \cdot 6 \cdot 7A^5}x^7 + \&c.;$

$+$ &c.; and the series $1+qx+rx^2+sx^3+tx^4+$ &c. $=1+\frac{B}{A}x+$

$$\frac{6CA-2B^2}{1\cdot 2A^2}x^2+\frac{18CAB-8B^3}{1\cdot 2\cdot 3A^3}x^3+\frac{36C^2A^2-8B^4}{1\cdot 2\cdot 3\cdot 4A^4}x^4+$$

$$\frac{180C^2A^2B-120ACB^3+16B^5}{1\cdot 2\cdot 3\cdot 4\cdot 5A^5}x^5+\frac{216C^3A^3+216A^2C^2B^2-288ACB^4+64B^6}{1\cdot 2\cdot 3\cdot 4\cdot 5\cdot 6A^6}x^6$$

$+$ &c.

The terms of these two series can easily be deduced by the subsequent method. Let $Kx^{n-1}+L^{n-1}+Mx^n$, be successive terms of the series $Ax+Bx^2+Cx^3+$ &c., and $K'x^{n-2}+L'x^{n-1}$ successive terms of the series $1+qx+rx^2+sx^3+tx^4+$ &c.; then will $M=\frac{2A^2\times B\times K'+6CAK-2B^3K}{n\cdot n-1\times A^3}$ and $L'=\frac{n\times A\times M-B\times nL}{A^2}$.

*Cor.* 1. Let $B=0$, and the two series $Ax+Bx^2+Cx^3+Dx^4+$ &c. and $1+qx+rx^2+$ &c. become respectively $Ax+\frac{2\cdot 3}{2\cdot 3}Cx^3+$

$$\frac{2^2\cdot 3^2}{2\cdot 3\cdot 4\cdot 5}\times\frac{C^2}{A}x^5+\frac{2^3\cdot 3^3}{2\cdot 3\cdot 4\cdot 5\cdot 6\cdot 7}\times\frac{C^3}{A^2}\times x^7+\frac{2^4\cdot 3^4}{2\cdot 3\cdot 4\cdot 5\cdot 6\cdot 7\cdot 8\cdot 9}$$

$\times\frac{C^4}{A^3}x^9+$ &c., and $1+\frac{2\cdot 3}{1\cdot 2}\times\frac{C}{A}x^2+\frac{2^2\cdot 3^2}{1\cdot 2\cdot 3\cdot 4}\times\frac{C^2}{A^2}x^4+$

$$\frac{2^3\cdot 3^3}{1\cdot 2\cdot 3\cdot 4\cdot 5\cdot 6}\times\frac{C^3}{A^3}x^6+\text{ &c.}$$

If in these series for A be substituted 1, and for C be substituted $-\frac{1}{2\cdot 3}$, there will result the series $x-\frac{x^3}{2\cdot 3}+$

$\frac{x^5}{2\cdot 3\cdot 4\cdot 5}-$ &c., and $1-\frac{x^2}{1\cdot 2}+\frac{x^4}{1\cdot 2\cdot 3\cdot 4}-$ &c. which give the sine and cosine in terms of the arc $x$.

*Cor.* 2. Let $C=0$, and the above-mentioned series $Ax+Bx^2+$ &c. becomes $Ax+\frac{2}{1\cdot 2}Bx^2*-\frac{2^3}{1\cdot 2\cdot 3\cdot 4}\times\frac{B^3}{A^2}x^4-\frac{2^4}{1\cdot 2\cdot 3\cdot 4\cdot 5}\times$

$$\frac{B^4}{A^3}x^5*+\frac{2^6}{1\cdot 2\cdot 3\cdot 4\cdot 5\cdot 6\cdot 7}\times\frac{B^6}{A^5}\times x^7+\frac{2^7}{1\cdot 2\cdot 3\cdot 4\ldots 8}\times\frac{B^7}{A^6}x^8*-$$

$$\frac{2^9}{1\cdot 2\cdot 3\cdot 4\ldots 10}\times\frac{B^9}{A^8}x^{10}-\frac{2^{10}}{1\cdot 2\cdot 3\ldots 11}\times\frac{B^{10}}{A^9}x^{11}+\text{ &c.}$$ The law of

this

this ſeries is, firſt, that every third term vaniſhes; and, ſecondly, the ſigns of every two ſucceſſive terms change alternately from + to − and − to +; and, laſtly, the co-efficient of the term $x^n$ is $\frac{2^{n-1}}{1 \cdot 2 \cdot 3 \ldots n} \times \frac{B^{n-1}}{A^{n-1}}$; and the ſeries $1 + qx + rx^2$ + &c. becomes $1 + \frac{B}{A}x - \frac{2B^2}{1 \cdot 2A^2}x^2 - \frac{2^3B^3}{1 \cdot 2 \cdot 3A^3}x^3 - \frac{2^3B^4}{1 \cdot 2 \cdot 3 \cdot 4A^4}x^4$ $+ \frac{2^4B^5}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5A^5}x^5 + \frac{2^6B^6}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \cdot 6A^6}x^6 + \frac{2^6 \times B^7}{1 \cdot 2 \cdot 3 \ldots 7A^7}x^7 -$ &c. In this ſeries the ſigns of three ſucceſſive terms alternately change from + to − and − to +; and the co-efficient of the term $x^n$ is $\frac{2^n \times B^n}{1 \cdot 2 \cdot 3 \cdot nA^n}$ or $\frac{2^{n-1} \times B^n}{1 \cdot 2 \cdot 3 \ldots nA^n}$ according as $n$ is diviſible by 3 or not.

2. Let a ſeries $1 + Px + Qx^2 + Rx^3 + Sx^4 + Tx^5 +$ &c. be of ſuch a formula, that if in it for $x$ be ſubſtituted $a + b$, there reſults a ſeries $1 + P \times \overline{a+b} + Q \times \overline{a+b}^2 + R \times \overline{a+b}^3 + S \times \overline{a+b}^4$ + &c. $= (1 + Pa + Qa^2 + Ra^3 + Sa^4 +$ &c.) $\times (1 + Pb + Qb^2 + Rb^3$ $+ Sb^4 +$ &c.) $+ (Aa + Ba^2 + Ca^3 + Da^4 +$ &c.) $\times (Ab + Bb^2 + Cb^3$ $+ Db^4 +$ &c.), then will the ſeries $Ax + Bx^2 + Cx^3 + Dx^4 +$ &c. $= Ax + Bx^2 + \left(\frac{2B^2}{3A} - \frac{PB}{3} + A \times \frac{A^2 + P^2}{6}\right)x^3 + \frac{2B^3 - 2PAB^2 + A^2 \times \overline{A^2 + P^2} \times B}{6A^3}x^4 +$ &c., and the ſeries $1 + Px + Qx^2 + Rx^3 +$ &c. $= 1 + Px + \frac{A^2 + P^2}{2}x^2 + \frac{2AB + P \times \overline{A^2 + P^2}}{6}x^3 + \frac{4B^2 + \overline{A^2 + P^2}^2}{24}x^4 +$ &c. Let $Kx^{n-1} + Lx^{n-1} + Mx^n$ be ſucceſſive terms of the ſeries $Ax + Bx^2 +$ $Cx^3 +$ &c., and $K'x^{n-1} + L'x^{n-1} + M'x^n$ ſucceſſive terms of the ſeries $1 + Px + Qx^2 + Rx^3 +$ &c.; then will $A \times L + P \times L' = n$ $\times M'$ and $B \times K + Q \times K' = n \cdot \frac{n-1}{2} \times M'$ expreſs the law of the ſerieſes.

*Cor.* Let $B=0$, then the series $Ax+Bx^2+Cx^3+Dx^4=A\times$ $(x+\frac{P^2\times A^2}{2\cdot 3}x^3+\frac{(P^2+A^2)^2}{1\cdot 2\cdot 3\cdot 4\cdot 5}x^5+\frac{(P^2+A^2)^3}{1\cdot 2\cdot 3\cdot 4\cdot 5\cdot 6\cdot 7}x^7+$ &c.), and the series $1+Px+Qx^2+Rx^3+$ &c. $=1+Px+\frac{P^2+A^2}{1\cdot 2}x^2+P\times\frac{P^2+A^2}{1\cdot 2\cdot 3}x^3+\frac{(P^2+A^2)^2}{1\cdot 2\cdot 3\cdot 4}x^4+P\times\frac{(P^2+A^2)^2}{1\cdot 2\cdot 3\cdots 5}x^5+\frac{(P^2+A^2)^3}{1\cdot 2\cdot 3\cdots 6}x^6+$ &c.; the co-efficient of the term $x^n$ will be $(P^2+A^2)^{\frac{n}{2}}$ or $P\times(P^2+A^2)^{\frac{n-1}{2}}$, according as $n$ is even or odd.

If in the equations before given for $x$ be ſubſtituted $a=b$ inſtead of $a+b$, then in the other quantities for $b$ ſubſtitute $-b$.

3. If in Caſe 2. the difference between the two quantities $(1+Pa+Qa^2+$ &c.$)\times(1+Pb+Qb^2+$ &c.$)$ and $(Aa+Ba^2+Ca^3+$ &c.$)\times(Ab+Bb^2+Cb^3+$ &c.$)$ is aſſumed $=1+P\times\overline{a+b}+Q\times\overline{a+b}^2+$ &c., then in the ſerieſes before given for A, B, C, &c. write reſpectively $\sqrt{-1}A$, $\sqrt{-1}B$, $\sqrt{-1}C$, &c., and there will reſult the correſponding ſerieſes.

The ſame principles may be applied to many other caſes.

4. Equations of theſe formulæ may be uſeful, when the ſums of the ſerieſes correſpondent to a value $(a)$ of $x$ are given, and the ſums of the ſeries correſpondent to a value $(a+b)$ of $x$ is required, $b$ having a ſmall ratio to $a$: for inſtance, let the given ſeries be $x-\frac{x^3}{2\cdot 3}+\frac{x^5}{2\cdot 3\cdot 4\cdot 5}-\frac{x^7}{2\cdot 3\cdots 7}+$ &c.; the equation found in the firſt caſe is $a+b-\frac{(a+b)^3}{2\cdot 3}+\frac{(a+b)^5}{2\cdot 3\cdot 4\cdot 5}-$ &c. $=(a-\frac{a^3}{2\cdot 3}+\frac{a^5}{2\cdot 3\cdot 4\cdot 5}-$ &c.$)\times(1-\frac{b^2}{1\cdot 2}+\frac{b^4}{1\cdot 2\cdot 3\cdot 4}-$ &c.$)$ $+(1-\frac{a^2}{1\cdot 2}+\frac{a^4}{1\cdot 2\cdot 3\cdot 4}-$ &c.$)\times(b-\frac{b^3}{2\cdot 3}+\frac{b^5}{2\cdot 3\cdot 4\cdot 5}-$ &c.$)$;

but

but $a-\frac{a^3}{2\cdot 3}+\frac{a^5}{2\cdot 3\cdot 4\cdot 5}-$ &c., and $1-\frac{a^2}{1\cdot 2}+\frac{a^4}{2\cdot 3\cdot 4}-$ &c. are the ſine ($s$) and coſine ($c$) of an arc $a$ of a circle whoſe radius is 1; and, conſequently, if the ſine $s$ and coſine $c$ of an arc $a$ be given, the ſine of an arc $(a+b)=s\times(1-\frac{b^2}{2}+\frac{b^4}{24}-$ &c.$)+c(b-\frac{b^3}{2\cdot 3}+\frac{b^5}{2\cdot 3\cdot 4\cdot 5}-$ &c.), which ſeries, if $b$ be very ſmall in proportion to $a$, converges much faſter than the common ſeries for finding the ſine from the arc: it has been given from different principles in the Meditationes, and is alſo eaſily deducible from the ſeries for finding the ſine and coſine from the arc by the propoſitions uſually given in plane trigonometry: the coſine of the ſame arc $(a+b)=c\times(1-\frac{b^2}{1\cdot 2}+\frac{b^4}{2\cdot 3\cdot 4}-$ &c.$)-s\times(b-\frac{b^3}{1\cdot 2\cdot 3}+\frac{b^5}{1\cdot 2\cdot 5}-$ &c.),

Ex. 2. Let the ſeries be $\overline{a+b}+\frac{\overline{a+b}^3}{2\cdot 3}+\frac{\overline{a+b}^5}{2\cdot 3\cdot 4\cdot 5}+$ &c. $=(a+\frac{a^3}{2\cdot 3}+\frac{a^5}{2\cdot 3\cdot 4\cdot 5}+$ &c.$\times(1+\frac{b^2}{1\cdot 2}+\frac{b^4}{1\cdot 2\cdot 3\cdot 4}+$ &c.$)+(1+\frac{a^2}{1\cdot 2}+\frac{a^4}{1\cdot 2\cdot 3\cdot 4}+$ &c.$)\times(b+\frac{b^3}{1\cdot 2\cdot 3}+\frac{b^5}{2\cdot 3\cdot 4\cdot 5}+$ &c.$)$; but $a+\frac{a^3}{1\cdot 2\cdot 3}+$ &c.$)=x$, and $1+\frac{a^2}{1\cdot 2}+\frac{a^4}{1\cdot 2\cdot 3\cdot 4}+$ &c. $=\sqrt{1+x^2}$, if $a$ be the hyperbolic log. of $x+\sqrt{1+x^2}$; therefore $a+b+\frac{\overline{a+b}^3}{2\cdot 3}+\frac{\overline{a+b}^5}{2\cdot 3\cdot 4\cdot 5}+$ &c. $=x\times(1+\frac{b^2}{2}+\frac{b^4}{2\cdot 3\cdot 4}+$ &c.$)+\sqrt{1+x^2}\times(b+\frac{b^3}{2\cdot 3}+$ &c·

Let $b+\frac{b^3}{2\cdot 3}+\frac{b^4}{2\cdot 3\cdot 4\cdot 5}+$ &c. $=y$, and $(x+\sqrt{1+x^2}\times(y+\sqrt{1+y^2})=V$, then will $\overline{a+b}+\frac{\overline{a+b}^3}{2\cdot 3}+\frac{\overline{a+b}^5}{2\cdot 3\cdot 4\cdot 5}+$ &c. $=\frac{1}{2}V-\frac{1}{V}$.

5. Let a quantity P be a function of $x$, or the fluent of a function of $x \times \dot{x}$, and the value X of it when $x = a$ be known, and the value of it when $x = a + b$ be required. Find a series of which the first term is X, and which proceeds according to the dimensions of $b$, if $b$ be a very small quantity, and in general at least so small that the series from $x = a$ to $x = a + b$ neither becomes infinite or 0.

In the same manner, if an algebraical or fluxional equation or equations, expressing the relations between $x, y, z, v$, &c. be given, find the correspondent values of $y, z, v$, &c. to $x = a$, which let be Y, Z, V, &c.; then find series for $y, z, v$, &c. of which the first terms let be Y, Z, V, &c. respectively, and which proceed according to the dimensions of $b$, but subject to the same conditions as in the preceding case.

From fluxional equations may be deduced series which express the value of $y$, &c. in terms of $x$, and always diverge, or always converge, whatever may be its value, as appears from the Meditationes.

XVIII. *On the Reſolution of attractive Powers.* *By* Edward Waring, *M. D. F. R. S. and* Lucaſian *Profeſſor of Mathematics at* Cambridge.

Read May 28, 1789.

1. A FORCE acting at a given point may be reſolved by an infinite number of ways into two, three, or more ($n$) forces acting at the ſame point, either in the ſame or different planes with the given force and each other; and, *vice verſâ*, any number of ſuch forces acting in the ſame or different planes may be reduced into one.

Ex. Fig. 1. Tab. III. Let a body A be acted on by three forces AB, AC, and AD, not being in the ſame plane; reduce any two of them AB and AC to one AE, by compleating the parallelogram ABEC; then reduce the two forces AE and AD to one AF by completing the parallelogram AEFD, and the three forces AB, AC, and AD, are reduced to the one AF.

2. If $n$ forces act on the body A at the ſame time, and any $(n-1)$ of them be reduced to one, the force reſulting will be ſituated in the ſame plane with the remaining, and force equivalent to the $(n)$ forces.

3. If one force $a$ be reſolved into ſeveral others $x, y, z, v$, &c. ſituated in different planes, and the ſines of the angles, which the forces $y, z, v$, &c. contain with the plane made by the direction of the forces $x$ and $a$ be reſpectively $s, s', s''$, &c. then will $sy \pm s'z \pm s''v \pm$ &c. $= 0$.

PRO-

PROBLEM I.

Fig. 2. Given the law of attraction of each of the parts of a given line in terms of their distance from a given point P; to find the attraction of the whole line *ab* on the point P.

Find the attraction of the line *ab* on the point P in the two directions P*f* and *fb* by the following method. Draw P*x* from the point P to any point *x* of the line *ab*, the force acting on the point P by the particle *xy* will be the given function (determined from the given law of attraction) of the distance into the particle; draw also P*b* perpendicular from the point P to the line *ab*, and let P*f* = *a*, *bf* = *b*, and *fx* = *y*; then will the distance P*x* = $\surd(a^2 \pm 2by + y^2)$, and the function of the distance into the particle $xy = \varphi(\surd(a^2 \pm 2by + y^2)) \times \dot{y} = F(y) \times \dot{y}$; let this be denoted by *lx* situated in the line P*x*, which resolve into two others $nx = \frac{\dot{y} \times F:(y)}{Px = \surd(a^2 \pm 2by + y^2)}$ situated in the line *ab*, and *ln* (in a direction parallel to P*f*) $= \frac{a\dot{y} \times F:(y)}{\surd(a^2 \pm 2by + y^2)}$; find the fluents of the fluxions $\frac{\dot{y} \times F:(y)}{Px}$ and $\frac{a\dot{y} \times F:(y)}{Px}$ contained between the values *af* and *fb* of the line *fx* = *y*, which suppose Y and V respectively; through the point *p* draw P*y* parallel to *fb* = Y, and in the line P*f* assume P*u* = V; complete the parallelogram P*uzy*; P*z* will be the force of the line *ab* on the point P.

*Cor.* If F : (*y*) varies as any power or root (2*n*) of the distance P*x* = $\surd(a^2 \pm 2by + y^2)$, and $n - \frac{1}{2}$ be an integer affirmative number or 0, the fluents Y and V of both the fluxions can be found in finite algebraical terms of *y*; if $n - \frac{1}{2}$ be an integer negative number, both the fluents can be found in the above-

mentioned finite terms together with the arc of a circle, whoſe radius is $\sqrt{a^2-b^2}$ and tangent $y \mp b$, unleſs $n-\frac{1}{2}=-1$, in which caſe the fluent Y involves that circular arc, and alſo the logarithm of $y^2 \pm 2by + a^2$. If $n-\frac{1}{2}$ denotes a fraction whoſe denominator is 2, both the fluents can be expreſſed by the finite terms together with the log. of $y \pm b + \sqrt{(y^2 \pm 2by + a^2)}$. If the fluents be given, when $n$ is a given quantity, and $n-\frac{1}{2}$ not a whole affirmative number, from them can be deduced the fluents of any fluxions reſulting by increaſing or diminiſhing $n$ by a whole number, unleſs in the above-mentioned caſe of $n-\frac{1}{2}=-1$. If $b=0$, and conſequently the line P$f$ is perpendicular to the given line $ab$, the fluent Y will be expreſſed by the finite terms, unleſs $n-\frac{1}{2}=-1$, in which caſe it will be as $\frac{1}{2}$ log. $(y^2+a^2)$ when properly corrected.

Theſe fluxions $\dot{Y}$ and $\dot{V}$ may be transformed into others, whoſe variable quantity is $Px=u$ the diſtance from P, by ſubſtituting in the fluxions for $y$ and $\dot{y}$ their reſpective values $\sqrt{(u^2-a^2+b^2)} \mp b$ and $\frac{u\dot{u}}{\sqrt{(u^2-a^2+b^2)}}$, and conſequently for $\sqrt{(y^2 \pm 2by + a^2)}$ its value $u$.

## PROBLEM II.

Fig. 3. Given the attraction of each of the parts of a given ſurface in terms of their diſtance from a given point P, and an equation expreſſing the relation between an abſciſs $Ap=x$, and its correſpondent ordinates $pm=y$ of the ſurface; to find the attraction of the ſurface on the given point P.

Firſt, by the preceding propoſition find the attractions Y and V of any ordinate $m\,p\,m'$ in the directions of the ordinate $pm$ and of the line P$p$; and from the equation expreſſing the relation

relation between the abſciſs and ordinates of the given curve, find the abſciſs in terms of the ordinates $(pm)=\pi:(y)$, and thence $\dot{x}=\phi:(y)\times\dot{y}$ and $\sqrt{(a'^2\pm 2sa'x+x^2)}=\phi':(y)$, where $PA=a'$ and $s=$ coſine of the angle, which the abſciſs $Ap$ makes with the line PA; then find the fluents of the three fluxions $\dot{x}\times Y=\dot{y}\times Y\times\phi:(y)$, $\dot{x}\times\frac{V\times x}{\sqrt{(a'^2\pm 2sa'x+x^2}}=\phi:(y)\times\dot{y}\times\frac{\pi:(y)}{\phi:(y)}\times V$ and $\dot{x}\times\frac{a'V}{\sqrt{(a'^2\pm 2sa'x+x^2)}}=\dot{y}\times\frac{a'V}{\phi':(y)}$ contained between the values of $y$, which correſpond to the extreme values of $x$, which ſuppoſe Y′, V′, and Z; and draw through the point P the lines Py and Pz reſpectively parallel to the ordinates $pm$ and to the abſciſs $Ap$ and equal to $r\times Y'$ and $V'$; aſſume $Pu$ in the line $(PA)=t\times Z$, $r$ and $t$ denoting the ſines of the angles, which the ordinates $pm$ and line AP make with the abſciſs $Ap$: reduce theſe three forces Py, Pz, and Pu, to one $Pf$, and $Pf$ will be the force of the ſurface on the point P.

*Cor.* 1. If for $y$ and $\dot{y}$ be ſubſtituted their values in terms of $x$ and $\dot{x}$, deduced from the equation expreſſing the relation between the abſciſs $Ap$ and ordinate $pm$ of the given curve, thence will be deduced the above-mentioned fluents Y, V, Y′, V′, and Z, in terms of $x$; and in the ſame manner, if for $x$ and $\dot{x}$ be ſubſtituted in the fluxions or fluents reſulting their values $\sqrt{(u^2-a'^2+1^2a'^2)}\mp sa'$, and its fluxion, there will reſult the above-mentioned fluxions or fluents in terms of $u$ the diſtance from the point P.

*Cor.* 2. Let the curve be a circle, of which A is the center, PA a line perpendicular to the plane of the circle, and the ordinate $pm$ perpendicular to the abſciſs $Ap$; the forces on each ſide of the abſciſs $Ap$ will be equal, and the force in the direc-

tion of the abscissa $Ap$ will be equal to that in the contrary direction; the force in the direction (PA) $= 4 \times \int \frac{a\dot{u}}{\sqrt{(u^2-a^2)}} \times \int \frac{u\dot{y}}{\sqrt{u^2+y^2}} \times F : (\sqrt{(u^2+y^2)}) = W$, in which $F : (\sqrt{u^2+y^2})$ is the function of the distance, according to which the given force on the particles varies; the fluent $\int \frac{u\dot{y}}{\sqrt{(u^2+y^2)}} \times F : \sqrt{(u^2+y^2)}$ is contained between the values $o$ and $\sqrt{(r^2+a^2-u^2)}$ of the quantity $y$, and the fluent W is contained between the values $a$ and $\sqrt{(a^2+r^2)}$ of the quantity $u$, where $a = PA$ and $r$ the radius of the circle; but the same force is $= 2 \times 3,14159$ &c. $\times \int a\dot{u} \times F : (u)$, where $F : (u)$ denotes the given function of the distance $(u)$, and the fluent is contained between the values $a$ and $\sqrt{a^2+r^2}$ of $u$.

## PROBLEM III.

To find the attraction of a given solid on a given point P. Find the attraction of every parallel section on that point by the preceding problem, and multiply it into the correspondent fluxion of the first abscissa AP, and also find the fluent of the resulting fluxion, which, properly corrected, multiply into the sine of the angle, which the first abscissa makes with the parallel sections, and the product will be proportional to the attraction of the solid on the given point P.

2. Fig. 4. Let the solid ABCH be generated by the rotation of a given curve round its axis AB, which passes through the point attracted P, and this solid be supposed to consist of small evanescent solids, whose bases are the surfaces EF, *ef*, &c. of spheres, of which the center is P, and altitudes F*f*, &c. the

increments of the base AB contained between the two contiguous surfaces EF and *ef*: from the points E and *e* of the curve draw ED and *ed* perpendicular to the axis AB, and ES perpendicular to the arc E*e* of the given curve at the point E, and meeting the axis AB in S; then will the evanescent solid $EFfe = p \times PE \times FD \times Ff = p \times FD \times PS \times Dd$ (because $Ff = \frac{PS \times Dd}{PE}$) $= p \times \overline{\sqrt{(z^2+y^2)} - z} \times \overline{z\dot{z} \mp y\dot{y}}$, where $z$ and $y$ denote respectively the abscis PD, and its correspondent ordinate DE of the given curve.

The increment of the attraction of the surface EF on the point P in the direction PD will be as the increment of the surface $(p \times PE \times Dd) \times \frac{PD}{PE}$ × force of each particle $= p \times PD \times Dd \times$ given force of the particle; but the fluent of the fluxion $PD \times Dd$ contained between the points E and F is $= \frac{1}{2}PE^2 - \frac{1}{2}PD^2 = \frac{1}{2}ED^2$, whence the attraction of the evanescent solid $EFfe$ is as $\frac{1}{2}p \times ED^2 \times Ff \times F : (\sqrt{x^2+y^2})$ force of each given particle at the distance $(PE = \sqrt{(x^2+y^2)}) = \frac{1}{2}p \times ED^2 \times \frac{PS}{PE} \times Dd \times F : (\sqrt{z^2+y^2}) = \frac{1}{2}py^2 \times \frac{z\dot{z} \mp y\dot{y}}{\sqrt{(z^2+y^2)}} \times F : (\sqrt{(z^2+y^2)})$; the fluent of which, properly corrected, is as the attraction of the solid on the point P; $p$ denotes the circumference of a circle, whose radius is 1.

*Cor.* 1. The fluxion of this solid is $\frac{1}{2}py^2\dot{z} = \dot{Y}$ which deduced from the preceding principles $= p \times (\sqrt{(z^2+y^2)} - z) \times (z\dot{z} \mp y\dot{y}) = \dot{V}$, and consequently their fluents between two values of $z$, which correspond to two values of $y = o$, will be equal to each other.

*Cor.*

*Cor.* 2. The increment of the attraction of this solid as given in this proposition $\frac{1}{2}p \times y^3 \times \frac{z\dot{z}+y\dot{y}}{\sqrt{(z^2+y^2)}} \times F : (\sqrt{(z^2+y^2)} = \dot{U}$, but in the preceding proposition the force of a circle on the point $P = p \times \int a\dot{u} \times F : (u)$, where $u = \sqrt{(z^2+y^2)}$ and $a = z$, and $y$ or $u$ the only variable quantity contained in the fluxion; and consequently the fluxion of the attraction of the solid $p \times \dot{z} \int z\frac{y\dot{y}}{\sqrt{z^2+y^2}} \times F : ((z^2+y^2)^{\frac{1}{2}}) = \dot{W}$; therefore, if for the fluent of $\frac{zy\dot{y}}{\sqrt{(z^2+y^2)}} \times F : ((z^2+y^2)^{\frac{1}{2}})$ be substituted its fluent contained between the values $a$ and the value of $y$, which in the given equation corresponds to $z$; then the fluents of $\dot{U}$ and $\dot{W}$ contained between the two values of $z$, which corresponds to two values of $y = o$, will be equal to each other.

The difference of the fluents of $\dot{Y}$ and $\dot{V}$, &c. contained between any other two values of $z$, can easily be deduced from the difference of two segments of spheres.

1. It may not be improper to remark in this place, that from different methods of finding the sum of quantities, the fluents of fluxions, the integrals of increments, &c. quantities may often be deduced equal, which otherwise cannot without some difficulty; of which instances are contained in the Meditationes, and I shall here subjoin one or two more to those already given in this Paper.

Ex. 1. Any curvilinear area ABC, &c. may be supposed to consist of evanescent areas EF*ef*, of which the base EF is the arc of a circle, whose radius is $PE = \sqrt{(z^2+y^2)}$ and sine $ED = y$, and altitude F*f*, and consequently the fluxion of the area $= Ff \times$ arc (A) of a circle whose radius is PE and sine $ED =$

$\frac{PS}{PE} \times \dot{z} \times A = \frac{z\dot{z} \mp y\dot{y}}{\sqrt{(z^2+y^2)}} \times A = \dot{V}$; the fluent of $\dot{V}$ contained between the two values of $z$ which correſpond to two values of $(y) = o$ will be equal to the fluent of $y\dot{z}$ contained between the ſame two values of $z$.

Ex. 2. The attraction of any circular arc EF in the direction PD on a point P (P being the center of a circle, of which EF is an arc, and ED the ſine of that arc) will be as ED × force at diſtance PE = ED × F : (PE); for the attraction in the direction PD$l'$F at the point $x$ is as the increment of the arc $xy \times F : (PE) \times \frac{Pl}{Px}$ ($xl$ and $yl'$ being at right angles to PF) $= U \times \frac{Px}{xl} \times \frac{Pl}{Px} \times F : (PE) = \frac{U' \times Pl}{ux} \times F : (PE) = \frac{u\dot{u}}{\sqrt{PE^2 - u^2}} \times F : (PE)$, if $u = Pl$; and conſequently the fluent of it is as $\sqrt{PE^2 - u^2} \times F : (PE) = ED \times F : (PE)$, and the attraction of the ſurface EF$ef$ will be as $ED \times Ff \times F : (PE) = ED \times \dot{z} \times \frac{PS}{PE} \times F : (PE) = y \times \frac{z\dot{z} \mp y\dot{y}}{\sqrt{(z^2+y^2)}} \times F : ((z^2+y^2)^{\frac{1}{2}} = \dot{V}$; the attraction of the curve will alſo vary as $\int \dot{z} \int \frac{u\dot{u} \times F : ((u^2+z^2)^{\frac{1}{2}})}{(z^2+u^2)^{\frac{1}{2}}} = W$, in which the fluent of $\frac{u\dot{u} \times F : ((z^2+u^2)^{\frac{1}{2}})}{(z^2+u^2)^{\frac{1}{2}}}$ is contained between $u = o$ and $u = y$; the fluents of $\dot{V}$ and $\dot{W}$ contained between two values of $z$, which correſpond to two values of $y = o$, will be equal to each other.

2. From a ſimilar method may be deduced equalities between other like fluents, for the curve may be ſuppoſed to conſiſt of other ſimilar curve ſurfaces equally as circles, and the ſolid of ſimilar ſegments of other ſolids equally as ſpheres.

3. From the ſame principles may innumerable ſerieſes equal to each other be deduced; for by different converging ſerieſes find

find the ſum of the ſame quantity or quantities, and there will reſult ſerieſes equal to each other: for inſtance (fig. 5), if the time of falling down the arcs AC and BC and their interpolations from the principles delivered in the Meditationes Analyticæ, of which the difference let be D; find the difference between the times of a body's falling through BC when it began to fall from A and from B by a ſeries proceeding according to the dimenſions of $AB = o$ a ſmall quantity; and find, by a ſeries of the ſame kind, the time of falling through AB; the ſum of theſe two ſerieſes will be equal to D. Similar propoſitions may be deduced from fluxional equations.

4. In ſome caſes the ratios of the times of bodies falling through ſome particular diſtances to each other may be eaſily known; for inſtance, let the force vary as the $m-1$ power of the diſtance ($x$), and $a$ be the diſtance from which the body began to fall, then the velocity varies as $\sqrt{(a^m - x^m)}$, and the increment of the time as $\frac{\dot{x}}{\sqrt{(a^m - x^m)}}$; but if the parts of different curves are proportional, then will $a$, $x$, and $\dot{x}$ vary in the ſame ratio as each other, and conſequently the time through proportional parts of the diſtance will vary as $a^{\frac{2-m}{2}}$; and if the bodies be reſiſted likewiſe by a force which varies as the $\frac{2m-2}{m}$ power of the velocities, then the times through proportional parts will vary as before, that is, as $a^{\frac{2-m}{2}}$, where $a$ denotes the proportional diſtances from the points where the forces and reſiſtances are equal.

PRO-

PROBLEM IV.

1. Fig. 6. Given an equation expreſſing the relation between the two abſciſſæ $z = AP$ and $x = Pp$ and their correſpondent ordinates $y = pm$ of a ſolid, to find its ſolid contents contained between two values of its firſt abſciſſæ $z$. Aſſume $z$ as an invariable quantity, and from the equation reſulting find the fluent $Z$ of $y\dot{x}$ contained between the extreme values of $x$ or $y$; then find the fluent of $Z\dot{z}$ contained between the given values of $z$, and the fluent multiplied into the product of the ſines of the angles, which the firſt abſciſſa makes with the plane of the ordinates and ſecond abſciſs, and the ſecond abſciſs makes with its correſpondent ordinates, will be the ſolid content required.

2. Fig. 7. Let the firſt abſciſs $z$ of a ſolid be perpendicular to the planes of the ordinates, and the ſecond abſciſs $Pp = x$ perpendicular to the ordinates themſelves $pm = y$. Firſt, aſſume the firſt abſciſs as invariable, and find the increment of the arc $p'm = (\dot{x}^2 + \dot{y}^2)^{\frac{1}{2}}$, then aſſume the ſecond abſciſs $Pp$ as conſtant, and let $mu$ be the fluxion of the ordinate $y$ or $u$, when the fluxion of the firſt abſciſs is $\dot{z} = ul$, where $ul$ is perpendicular to the plane of the ordinates $p'pm$, and $l$ a point of the ſurface of the ſolid; draw $uh$ perpendicular to the arc $p'm$, and ſince $ul$ is conſtituted at right angles to the plane $pp'm$, $lh$ will cut the arc $p'm$ at right angles; but $uh = \frac{um \times pp'}{p'm} = \frac{u\dot{x}}{\sqrt{(\dot{x}^2 + \dot{y}^2)}}$, $lh = (hu^2 + lu^2)^{\frac{1}{2}} = \left(\frac{u^2\dot{x}^2}{\dot{x}^2 + \dot{y}^2} + \dot{z}^2\right)^{\frac{1}{2}}$ the fluxion of the ſurface will be $lh \times \sqrt{(\dot{x}^2 + \dot{y}^2)}$. From the given equation expreſſing the relation between the two abſciſſæ $z$ and $x$ and ordinates $y$ find, by aſſuming $z$ invariable $p\dot{x} = \dot{y}$, and by aſſuming $x$ invariable $q\dot{z} = \dot{y}' = \dot{u}$,

$\dot{y}' = \dot{u}$, which being substituted for their values in the quantity $lh \times \sqrt{(\dot{x}^2 + \dot{y}^2)}$, there will result $(q^2 + p^2 + 1)^{\frac{1}{2}} \times \dot{x} \times \dot{z} = A\dot{x}\dot{z} = \frac{(q^2 + p^2 + 1)^{\frac{1}{2}}}{p} \times \dot{y} \times \dot{z} = B\dot{y}\dot{z}$; in A and B for $y$ and $x$ respectively substitute their value deduced from the given equation, and let the resulting quantities be $A'\dot{x}\dot{z}$ and $B'\dot{y}\dot{z}$, where A′ is a function of $x$ and $z$, and B′ a function of $y$ and $z$; find the fluent of $A'\dot{x}\dot{z}$ from the supposition that $x$ is only variable contained between the extreme values of $x$ to a given value of $z$, which let be $L\dot{z}$, then find the fluent of $L\dot{z}$ by supposing $z$ only variable contained between given values of $z$, and it will be the surface of the solid contained between those values.

The same may be deduced by finding the fluent of $B'\dot{y}\dot{z}$ on the supposition that $y$ is the only variable quantity contained between the extreme values of $y$ as before of $x$ to a given value of $z$, which let be $L'\dot{z}$; then will the fluent of $L'\dot{z}$ contained between the given values of $z$ be the surface required.

If the solid be a cone generated by the rotation of a rectangular triangle round a side containing the right angle as an axis; $hu$ will be a given quantity, if $\dot{z}$ be given.

If the above-mentioned angles are given, but not right ones, the arc $p'm$ and perpendicular $l'h$ can easily be deduced, and consequently the increment of the surface.

3. To define a curve of double curvature, it is necessary to have two equations expressing the relation between the abscissæ $z$ and $x$ and their ordinates ($y$) given, and if the angles which they respectively make with each other be right ones; the fluxion of the arc as given in the *Proprietates Curvarum* is $(\dot{z}^2 + \dot{x}^2 + \dot{y}^2)^{\frac{1}{2}}$. Find its value from the two given equations in terms of $x$, $y$, or $z$, multiplied into its respective fluxions, and its fluent, properly corrected, will be the length of the arc required.

If

If the angles are not right, they may eaſily be reduced to them.

4. The attractions of theſe ſurfaces, curves, &c. on a given point P may be deduced from the preceding principles of finding the attractions of each of the parts in the directions of the firſt abſciſſa, which paſſes through the point P, the ſecond abſciſſa, and the ordinates, and then finding the integrals of theſe increments.

From the method which determines the attraction of a body, ſurface, &c. on a given point can be determined the attraction of a body, &c. on any number of points, and conſequently the attraction of one body, &c. on another, &c.

It is ſometimes advantageous to transform the firſt abſciſs, that it may paſs through the point attracted; and the abſciſſæ and ordinates, that they may be at right angles to each other, &c.

## PROBLEM V.

1. Fig. 8. Given an equation expreſſing the relation between the two abſciſſæ AP and P$p$ of a ſolid, and their correſpondent ordinates $pm$, or AP′, P′$p$′, and $p'm'$; to transform the firſt abſciſſa into any other L$h$.

Let the abſciſſa L$h$ begin from a point L of the firſt abſciſſa AP, and meet an ordinate $pm$ in the point $h$; draw $hp$, and let the ſines of the angles P$pm$, P$hp$, and $p$P$h$; LP$h$, P$h$L, and PL$h$, be denoted reſpectively by $r$, $s$, and $t$, &c. $r'$, $s'$, and $t'$; through a point $b$ of the line P$h$ draw $p'b'm'$ parallel to $pm$, and L$h = z$, $hb' = x$, and $b'm' = y$: in the given equation for AP, P$p$, and $pm$ ſubſtitute reſpectively their correſpondent

reſpondent values $\frac{t'z}{r'} \pm AL\,(a)$, $\frac{tt'z}{rr'} \pm \frac{tx}{r}$ (for $Pb = \frac{t'z}{r'}$ and $Pb' = Ph \pm bb' = \frac{t'z}{r'} \pm x$), and $y \pm \frac{tt'z}{rr'} \pm \frac{tx}{r}$; there reſults an equation to the ſame ſolid expreſſing the relation between the two abſciſſæ $z = Lb$ and $x$, and their correſpondent ordinates $y$.

1. 2. If the abſciſs $Lb$ does not begin from L, a point in the firſt given abſciſs AP, but from M a point given out of it, it may be reduced to the preceding caſe, by drawing from M a line $MN = c$ to the plane of the firſt and ſecond abſciſſæ parallel to the ordinates $pm$; and from N to the firſt abſciſſa a line $NO = b$ parallel to the ſecond abſciſſæ, and ſubſtituting in the equation expreſſing the relation between AP, $Pp$, and $pm$ for AP, $Pp$, and $pm$ reſpectively $z \pm AO$ $(a)$, $x \pm b$ and $y \pm c$; and there reſults the equation required expreſſing the relation between the two abſciſſæ $z$ and $x$, and their correſpondent ordinates $y$, of which the firſt abſciſſa $z$ paſſes through the point M.

2. To change the ſecond abſciſſa $Pp$ into any other $Lb$, the firſt abſciſſa and ordinates remaining the ſame. In the preceding figure let L be conſidered as a moveable point of the firſt abſciſs AL, and the ſines of the reſpective angles denoted by the ſame letters as before, and $Lb = x$, $AL = z$, and $bm = y$; in the given equation for AP, $Pp$, and $pm$, ſubſtitute $z \pm \frac{t'x}{r'}$, $\frac{st'x}{rr'}$, and $y \pm \frac{tt'x}{rr'}$; and there will reſult the equation required expreſſing the relation between $z$ and $x$ the abſciſſæ, and their correſpondent ordinates $y$.

3. Fig 8. To change the ordinates, the abſciſſæ remaining the ſame, draw $p'm$ an ordinate transformed, $p'b$ parallel to the firſt abſciſſa AP, and meeting a ſecond abſciſſa, of which

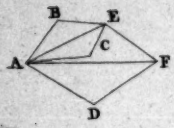
$pm$ is an ordinate in $h$: for the ſines of the angles $p'hp$, $hpp'$, and $hp'p$; $p'pm$, $pmp'$, and $pp'm$ write $r$, $s$, and $t$, $r'$, $s'$, and $t'$; and for AP′, P′$p'$, and $p'm$ reſpectively $z$, $x$, and $y$; then ſubſtitute in the given equation for AP, P$p$, and $pm$, their reſpective values $z\,(\mathrm{AP}') = \pm\frac{ts'}{rr'} \times y$, $x\,(\mathrm{P}'p' = \pm\frac{tr'}{rr'}y$, and $\frac{t'}{r'}y$; and there reſults an equation to the ſolid expreſſing the relation between the two abſciſſæ AP′ and P′$p'$ and the tranſformed ordinates $p'm$.

From theſe caſes, which are eaſily reducible to one, may be tranſformed any given abſciſſæ and their correſpondent ordinates into any other containing given angles, &c. with the before-mentioned abſciſſæ and ordinates.

In the properties of curve lines, firſt publiſhed in 1762, is given a method of deducing the equation to any ſection of the ſolid, and in particular the caſe of deducing the equation to the projection of any curve on a given plane.

From the principles given in this, and the Paper on centripetal forces, which the Royal Society did me the honour to print, can be deduced the fluxional equations, whoſe fluents expreſs the relations between the abſciſſæ and their correſpondent ordinates of the curves deſcribed by bodies, of which the particles act on each other with forces varying according to given functions of their diſtances.

Fig. 1.



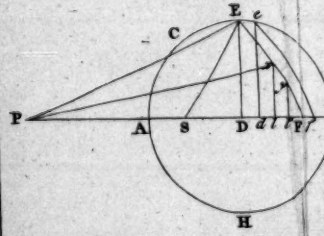



Fig. 7.

Fig. 2.

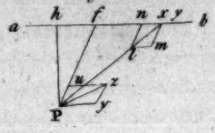



Fig. 3.

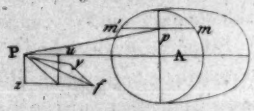



Fig. 4.

Fig. 5.

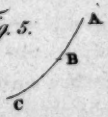



Fig. 6.

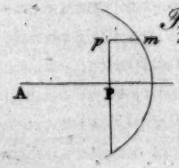



Fig. 8.

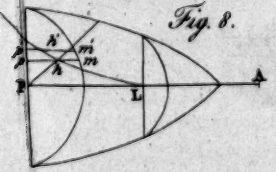
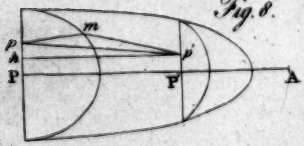



Fig. 8.



## XIX. *Experiments on the Congelation of Quickſilver in* England. *By Mr.* Richard Walker; *in a Letter to* Henry Cavendiſh, *Eſq. F. R. S.*

Read May 28, 1789.

SIR,

I NOW beg leave to trouble you with the particulars of my experiments relative to the congelation of mercury; to which I ſhall add an account of a few experiments, relating to the production of artificial cold, made ſince my laſt Paper was written.

Exp. 1. On December 28th laſt, a favourable opportunity offered of beginning ſome experiments on the congelation of mercury, which I was deſirous of effecting completely; how far I have ſucceeded will appear in the ſequel.

For this purpoſe I prepared a mixture of diluted vitriolic acid (reduced by water till its ſpecific gravity was to that of water as 1,5596 to 1) and ſtrong fuming nitrous acid, of each equal parts. I preferred this mixture of acid becauſe it has been found by Mr. Mc Nab, in Hudſon's Bay, to be capable of producing much greater cold, when the temperature of the materials at mixing is very low, than the nitrous acid alone; the former ſinking a ſpirit thermometer to $-54°\frac{1}{2}$, the latter never lower than $-46°$.

The glaſs tube of a mercurial thermometer, with its bulb half filled with mercury, was provided, this occurring to me

as a convenient method of aſcertaining when the mercury was congealed; for if, after being ſubjected to the cold of a frigorific mixture, the thermometer glaſs ſhould be taken out and inverted, and the mercury found to remain completely ſuſpended in that half of the bulb now uppermoſt, no doubt can remain of the ſucceſs of the experiment; an hydrometer, with its lower bulb half an inch in diameter, and three-fourths full of mercury, was likewiſe provided, in caſe any accident ſhould happen to the other.

It may be proper to premiſe here, that in all experiments of this kind I remove each veſſel, when the liquor it contains is ſufficiently cooled, out of the mixture in which it is immerſed for that purpoſe, immediately previous to adding the ſnow or ſalts with intention to generate a ſtill further increaſe of cold; and likewiſe prefer adding the ſnow or powdered ſalts to the liquor, inſtead of pouring the liquor upon theſe: it is neceſſary alſo to ſtir about the ſnow or ſalts, whilſt cooling in a frigorific mixture, from time to time, otherwiſe it will freeze into a hard maſs, and fruſtrate the experiment.

A half-pint glaſs tumbler, containing two ounces and a half of the above-mentioned diluted mixture of acids, being immerſed in mixtures of nitrous acid and ſnow, until the liquor it contained was cooled to $-30°$, was removed out of the mixture and placed upon a table; ſnow, likewiſe previouſly cooled in a frigorific mixture to $-15°$, was added by degrees to the liquor in the tumbler, and the mixture kept ſtirring until a mercurial thermometer ſunk to $-60°$, where it remained ſtationary; the hydrometer was then immerſed in the mixture (the thermometer glaſs having been broken in the courſe of the experiment), and ſtirred about in it for a ſhort time, and on taking the hydrometer out, and gently ſhaking it, I

perceived the mercury had already acquired the conſiſtence of an amalgam, and after immerſing it again for a few minutes, and then taking out and inverting it, I was gratified for the firſt time with the ſight of mercury in a ſtate of perfect congelation. I applied my hand to the inverted glaſs bulb; this ſoon looſened the ſolid mercury, which, on ſhaking the hydrometer, was diſtinctly heard to knock with force againſt the glaſs; it was then immerſed a ſecond time, and when taken out was found adhering to the glaſs as before. I now inverted the glaſs again, and kept it in that ſituation until the whole of the mercury melted, and dropped down globule after globule into the ſtem of the hydrometer. The interval of time from taking the mercury out of the frigorific mixture in a ſolid ſtate, the laſt time, to its perfect liquefaction, was not noticed; but, upon recollection immediately afterwards, was ſuppoſed to be not leſs than three or four minutes. In a ſucceeding experiment this circumſtance was attended to, and the frozen mercury, weighing ſeven ſcruples, was not entirely melted under ſeven minutes, the temperature of the air + 30°.

The experiment which follows I conſider the moſt extraordinary, becauſe it proves beyond a doubt, that mercury may be frozen not only here in ſummer, but even in the hotteſt climate, at any ſeaſon of the year, by a combination of frigorific mixtures, in the way deſcribed in the Philoſophical Tranſactions, Vol. LXXVII. p. 285. in which attempt to freeze mercury, made April 20, 1787, the temperature of the air and materials being + 45°, I certainly reached (without the aſſiſtance of ſnow or ice) the point of mercurial congelation; but had then no ſatisfactory proof that any part of the mercury was abſolutely congealed.

Exp.

Exp. 2. On December 30. three ounces of a mixture compoſed of ſtrong fuming nitrous acid two parts, and ſtrong vitriolic acid and water each one part, were cooled in a half pint tumbler immerſed in a frigorific mixture, till the temperature of the diluted mixture of acids was reduced to $-30°$. The tumbler was then removed out of the mixture, and vitriolated natron (GLAUBER's ſalt) in very fine powder, previouſly cooled to $-14°$ by a frigorific mixture, added by degrees to the liquor in the tumbler, ſtirring it together until the mercury in the thermometer ſunk to $-54°$. The hydrometer uſed in the former experiment, with its lower bulb three-fourths full of mercury, was now immerſed and ſtirred about in the mixture for a few minutes, when on taking it out, and inverting it, I had the ſatisfaction to find the ſame proof of the mercury being frozen as in the former inſtance. It was immediately ſhewn to the gentlemen preſent, who expreſſed likewiſe their entire ſatisfaction. Nearly four ounces of the powdered ſalt was added; but, I believe, ſome was added after the greateſt effect was produced. I had no nitrated ammonia by me, otherwiſe I ſhould have uſed upon this occaſion, inſtead of vitriolated natron alone, a mixture of theſe two ſalts in powder, in the proportion of ſeven parts of the former to eight of the latter. The temperature of the room in which theſe experiments were made was $+30°$ each time, and the mercury taken from a jar containing ſeveral pounds.

Exp. 3. By an experiment made purpoſely on January 10. laſt, at which Dr. BOURNE was preſent, I have found that mercury may be congealed tolerably hard, by adding freſh fallen ſnow, at the temperature of $+32°$, to ſtrong fuming nitrous acid, previouſly cooled to between $-25°$ and $-30°$, which may be very eaſily and quickly effected by immerſing

the veſſel containing the acid in a mixture of ſnow and nitrous acid.

I uſe the *fuming* nitrous acid upon all occaſions, becauſe that does not require to be diluted, cold being immediately produced on the ſmalleſt addition of ſnow.

Exp. 4. On January 12, at Dr. Thomson's requeſt, I repeated the experiment of freezing mercury, at the Anatomy School in Chriſt Church, in the preſence of the honourable Mr. Wenman, the rev. Dr. Hoare, Dr. Sibthorp, junior, Dr. Thompson, the rev. Mr. Jackson of Chriſt Church, and Mr. Wood of this place, a gentleman well known for his ingenuity in mechanics.

For this purpoſe were provided a ſpirit thermometer graduated very low, and a mercurial thermometer graduated to $-76°$, two thermometer glaſſes, with bulbs very near, if not quite, an inch in diameter each, one filled with mercury nearly to the orifice of the tube, which was left open, the other with its bulb half filled, and an hydrometer with its lower bulb (conſiderably leſs than either of the others) likewiſe half filled with mercury; the temperature of the room at this time $+28°$.

A pan, containing nine ounces of the mixture of acids prepared as in the firſt experiment, was placed in a larger pan, containing nitrous acid, and this, in a frigorific mixture of nitrous acid and ſnow, contained in another pan much larger. When the nitrous acid in the ſecond pan was cooled by this mixture to $-18°$, and the mixed acids in the ſmalleſt pan nearly as much ſnow at ſomewhat between $+20°$ and $+25°$, the temperature of the open air at that time, was added to the nitrous acid in the ſecond pan, until the ſpirit thermometer ſunk to near $-43°$; then the thermometer, with its bulb half filled, was immerſed a ſufficient time, and when taken

out,

out, the mercury in it was found congealed, and adhering to the glaſs. The pan containing the mixed acids, and which had been removed whilſt the ſnow was added to make the ſecond mixture, was now replaced in it, in order to be cooled; and when the mixture of acids was reduced to the temperature of $-34°$, ſnow previouſly cooled to $-18°$ was added, keeping the mixture ſtirred until the mercurial thermometer ſunk to $-60°$; its temperature by the ſpirit thermometer was then found to be $-51°$.

The three glaſſes containing the mercury to be frozen were now immerſed in this mixture, and having been moved about in it for a conſiderable time, during which the ſpirit thermometer roſe ſcarcely one degree, were then ſeverally taken out and examined.

As the examination of the frozen mercury was more immediately under the inſpection of Dr. THOMSON, I ſhall tranſcribe here that gentleman's account of the phænomena.

"When the freezing mixture was ſuppoſed to have produced its effect, the bulb which was completely filled was taken out, and broken on a flat ſtone by a moderate ſtroke or two with an iron hammer. This bulb was eleven or twelve lines in diameter.

The ſolid mercury was ſeparated into ſeveral ſharp and brilliant fragments, ſome of which bore handling for a ſhort time before they returned to a fluid form. One maſs, larger than the reſt, conſiſting of nearly one-third of the whole ball, afforded the beautiful appearance of flat plates, converging towards a center. Each of theſe plates was about a line in breadth at the external ſurface of the ball, becoming narrower as it ſhot inwards. Theſe facets lay in very different planes, as is common in the fracture of any cryſtallized ball, whether

whether of a brittle metal or of the earths, as in balls of calcareous ſtalactite. The ſolid brittle mercury in the preſent inſtance bore a very exact reſemblance, both in colour and plated ſtructure, to ſulphurated antimony, and eſpecially to the radiated ſpecimens from Auvergne, before they are at all tarniſhed.

Inſtead of a ſolid center to this ball, it ſeemed as if there had been a central cavity, of about two lines in diameter, a conſiderable portion of which was evident in the fragment juſt deſcribed, at that part to which the radii converged. It is indeed poſſible, that this may have been merely the receptacle of ſome part of the mercury remaining fluid at the center. The hollow within was ſhining, but its edges were neither ſoft nor mouldering; on the contrary, they were ſharp and well defined: nor was the brilliancy of the radii attributable to any exudation of mercury as from an amalgam.

In the two ſmaller bulbs, which were only half filled, the mercury preſerved its uſual luſtre on the ſurface in contact with the glaſs, as well as on that ſurface which it had acquired in becoming ſolid. The latter was occupied by a conical depreſſion, the gradations of which were marked by concentric lines.

One of theſe hemiſpheres was ſtruck with a hammer, as in the former inſtance, but was rather flattened and cruſhed than broken. The other, on being divided with a ſharp chiſſel, ſhewed a metallic ſplendour on its cut ſurface, but not equalling the poliſh of a globule of fluid mercury."

Thirteen ounces of ſnow in the whole were found to have been added to the mixed acids; but ſome was added to lower its temperature after the glaſſes containing the mercury were taken out, and the ſpirit thermometer had riſen a few degrees.

This was a day remarkably favourable for ſuch an experiment. My thermometer expoſed to the open air ſtood, at three quarters paſt eight this morning, at +6°, which is a very extraordinary degree of cold here; but this experiment was not begun till noon.

Exp. 5. On Jan. 14. I froze mercury at the Anatomy School again, in the preſence of the rev. the Dean of Chriſt Church, the rev. Dr. HORNSBY, and Dr. THOMSON.

Four ounces now of the mixture of acids, prepared as in the firſt experiment, were cooled in a tumbler to −20°, which required ſomewhat more than an equal weight of ſnow, cooled nearly to the ſame temperature, to produce the greateſt effect. This was ſomewhat leſs than in the laſt experiment, the ſpirit thermometer ſinking no lower than −46°, owing chiefly to the weather having become much warmer, the temperature of the open air being now +36°. The mercurial thermometer immerſed in this mixture ſunk to −55°, where it became ſtationary; then two thermometer glaſſes, one half filled with mercury, and the other filled to a conſiderable height up the the tube, after being immerſed ſome time, were examined. Upon breaking the ſhell of glaſs from the former of theſe, the mercury was found in a perfectly ſolid ſtate; but its upper ſurface, which was highly poliſhed, and of the colour of liquid mercury, inſtead of being only ſlightly depreſſed, as had been ſeen in every other inſtance which afforded an opportunity for inſpection, now formed a perfectly inverted hollow cone. This great depreſſion, as well as the concentric circles mentioned in a former inſtance, I ſuppoſe, might be owing to a rotatory motion accidentally given to it whilſt congealing. The ſolid mercury was beaten out, but having been ſuffered to lie ſome time on the table for inſpection, very quickly

melted into liquid globules. The flexibility of ſolid mercury was clearly to be obſerved in this beautiful ſpecimen; for the external ſurface, particularly the upper thin rim of the concave part, was evidently bent by the firſt gentle ſtroke of the hammer. The globe of mercury in the other glaſs, which was very ſmall, exhibited nearly the ſame phænomena, as in the inſtances before mentioned.

It happened in theſe experiments of mine, contrary to what has generally occurred to others, that the mercury never ſunk lower than $-60°$, ſeldom ſo low, in the thermometer, and but little below the point of mercurial congelation in the tubes of the thermometer glaſſes filled nearly up to the orifice, with a view to ſhew the contraction of mercury in becoming ſolid by its great deſcent in the tube. On reflecting on this circumſtance afterwards, it occurred to me, that the further deſcent of the mercury in theſe experiments was prevented not ſolely by the mercury freezing in the tube, the cauſe commonly aſſigned, but rather by the quick formation of a ſpherical ſhell of ſolid mercury within the bulb, by the ſudden generation of cold.

Dr. Beddoes expreſſing a deſire to exhibit ſolid mercury at his Lecture before his Claſs, I undertook to freeze ſome at the Laboratory on March 12th laſt, and now reſolved to ſatisfy myſelf reſpecting the cauſe which prevented the lower deſcent of the mercury in my former experiments. In this, as well as the former, the mercury in a thermometer graduated to $-60°$, and likewiſe in a thermometer glaſs, filled nearly to the orifice, which lengthened its ſcale to near $-250°$, ſunk only a few degrees below the point of mercurial congelation, and then remained ſtationary. After waiting ſome time, I took the thermometer out of the mixture, and obſerved the bulb apparently full, and the ſhort thread of mercury above unbroken.

I now embraced the lower part of the tube with my hand a few ſeconds, reſting it upon the upper part of the bulb; and upon taking it away, I found that the whole of the mercury had ſubſided into the bulb, which it did not now quite fill, a ſmall ſpace at the top of the bulb remaining empty. I then took out the thermometer glaſs, and applied my hand to the tube; but the mercury remained ſtationary until I ſunk my hand ſo as to communicate heat to that part of the bulb which is immediately connected with the tube, when the thread of mercury dropped entirely into the bulb. It was now immerſed again for a ſhort time, then taken out, and the ſhell of glaſs beaten off, which expoſed a globe of ſolid mercury, nearly an inch in diameter. This bore ſeveral very ſmart ſtrokes with a hammer before it began to liquify, but was not perfectly malleable.

In the courſe of theſe experiments, ſeveral fragments of the ſolid mercury were thrown into mercury in its ordinary liquid ſtate, and were found to ſink with conſiderable celerity.

In continuing my reſearches reſpecting the means of producing artificial cold, I have found that phoſphorated natron produces rather more cold by ſolution in the diluted nitrous acid than the vitriolated natron.

At the temperature of $+50°$, four parts of the diluted nitrous acid (prepared by mixing ſtrong nitrous acid with half its weight of water) required eight parts of that neutral ſalt in fine powder to be added, in order to cauſe the thermometer to ſink to $-6°$; and again, by the addition of five parts of nitrated ammonia in fine powder, the thermometer ſunk ſo low as $-16°$; in the whole ſixty-ſix degrees.

A mixture of this kind made the thermometer ſink from 80° (the temperature of the materials before mixing) to 0°.

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I was directed to the trial of this ſalt, by the like remarkable ſenſation of coldneſs without pungency, which, with its other ſimilar properties to ice, firſt induced me, whilſt purſuing the ſubject of cold, to try the effect of diſſolving the vitriolated natron in the mineral acids.

Equal quantities, by weight, of phoſphorated natron and vitriolated natron, were evaporated ſeparately over a gentle fire, until each was reduced to a perfectly dry powder. I then weighed them, and found the reſiduum of the phoſphorated natron ſomewhat lighter than that of the vitriolated natron; from whence it is probable the former contains the greateſt quantity of water of cryſtallization.

I have found, that each of the neutral ſalts which produce any remarkable degree of cold by ſolution in the mineral acids, *viz.* phoſphorated natron, vitriolated natron, and vitriolated magneſia, loſe this property entirely, when deprived by any means of their water of cryſtallization.

A ſhort time after I had firſt ſucceeded in freezing water in ſummer, by one mixture compoſed of three different ſalts in water (having been induced to try the effect of ſuch a method, from the conſideration that water, already ſaturated with one kind of ſalt, will diſſolve a portion of another, and after that a third, or even more), I met with the account of an experiment made by M. Homberg, related in one of the earlier Volumes of the Philoſophical Tranſactions, in which it is ſaid he produced an extraordinary degree of cold, by pouring a pint and a half of diſtilled vinegar upon two pounds of a powder compoſed of equal parts of crude ſal ammoniac and corroſive ſublimate, and ſhaking them well together. I immediately (July 30, 1786) prepared a mixture of this kind in ſmaller quantity, but found it produced only thirty-two degrees of cold,

cold, the temperature of the air and materials before mixing being 63°; which is no more than I have found may be effected by a ſolution in water of crude ſal ammoniac alone, previouſly dried and powdered.

By a trial made with great accuracy, I find, that even the mixture compoſed of diluted vitriolic acid and vitriolated natron is adequate to any uſeful purpoſe that may be required in the hotteſt country; for, by adding eleven parts of the ſalt in fine powder to eight parts of the vitriolic acid diluted with an equal weight of water, the thermometer ſunk from 80°, the mean temperature of the hotteſt climate, and to which theſe materials were purpoſely heated before mixing, to rather below 20°.

Vitriolated natron, added to the marine acid undiluted, produces very nearly as great a degree of cold as when mixed with the diluted nitrous acid. At the temperature of 50°, two parts of the acid, require three parts of the ſalt in fine powder, which will ſink the thermometer to 0°; and if three parts of a mixed powder, containing equal parts of muriated ammonia and nitrated kali, be added afterwards, the cold of the mixture will be increaſed a few degrees more.

The frigorific mixture above deſcribed, compoſed of phoſphorated natron and nitrated ammonia diſſolved in the diluted nitrous acid, being the moſt powerful, it will probably be found moſt convenient for freezing mercury, when ſnow is not to be procured. The materials for this purpoſe may be previouſly cooled in mixtures made of marine acid with vitriolated natron, muriated ammonia, and nitrated kali, in the proportions mentioned above, this being much cheaper than thoſe made with diluted nitrous acid, and very nearly equal in effect.

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In my laſt Paper I mentioned a freezing mixture, made by diſſolving a powder compoſed of equal parts of muriated ammonia and nitrated kali in water, and therein directed ſix parts of the mixed powder to be added to eight parts of water; but I have found ſince, that the beſt proportions are, five parts of the former to eight of the latter, by which I have ſunk the thermometer from 50° to 11°.

Having now proſecuted my ſubject relative to mixtures for generating artificial cold without the uſe of ice, from a poſſible method propoſed by Dr. WATSON (Eſſays, Vol. III. p. 139.), for freezing water in ſummer in this climate, and carried it on to a certain method of freezing, not only water, but even mercury, in the hotteſt climate, I now intend to take my leave of it.

I have the honour to be, &c.

RICHARD WALKER.

## XX. *Catalogue of a ſecond Thouſand of new Nebulæ and Cluſters of Stars; with a few introductory Remarks on the Conſtruction of the Heavens.* By William Herſchel, *L.L.D. F.R.S.*

Read June 11, 1789.

BY the continuation of a review of the heavens with my twenty-feet reflector, I am now furniſhed with a ſecond thouſand of new Nebulæ.

Theſe curious objects, not only on account of their number, but alſo in conſideration of their great conſequence, as being no leſs than whole ſidereal ſyſtems, we may hope, will in future engage the attention of Aſtronomers. With a view to induce them to undertake the neceſſary obſervations, I offer them the following catalogue, which, like my former one, of which it is a continuation, contains a ſhort deſcription of each nebula or cluſter of ſtars, as well as its ſituation with reſpect to ſome known object.

The form of this work, it will be ſeen, is exactly that of the former part, the claſſes and numbers being continued, and the ſame letters uſed to expreſs, in the ſhorteſt way, as many eſſential features of the objects as could poſſibly be crowded into ſo ſmall a compaſs as that to which I thought it expedient to limit myſelf.

The method I have taken of *analyzing* the heavens, if I may ſo expreſs myſelf, is perhaps the only one by which we can arrive

arrive at a knowledge of their conſtruction. In the proſecution of ſo extenſive an undertaking, it may well be ſuppoſed that many things muſt have been ſuggeſted, by the great variety in the order, the ſize, and the compreſſion of the ſtars, as they preſented themſelves to my view, which it will not be improper to communicate.

To begin our inveſtigation according to ſome order, let us depart from the objects immediately around us to the moſt remote that our teleſcopes, of the greateſt *power to penetrate into ſpace*, can reach. We ſhall touch but ſlightly on things that have already been remarked.

From the earth, conſidered as a planet, and the moon as its ſatellite, we paſs through the region of the reſt of the planets, and their ſatellites. The ſimilarity between all theſe bodies is ſufficiently ſtriking to allow us to comprehend them under one general definition, of bodies not luminous in themſelves, revolving round the ſun. The great diminution of light, when reflected from ſuch bodies, eſpecially when they are alſo at a great diſtance from the light which illuminates them, precludes all poſſibility of following them a great way into ſpace. But if we did not know that light diminiſhes as the ſquares of the diſtances encreaſe, and that moreover in every reflection a very conſiderable part is intirely loſt, the motion of comets, whereby the ſpace through which they run is meaſured out to us, while on their return from the ſun we ſee them gradually diſappear as they advance towards their aphelia, would be ſufficient to convince us that bodies ſhining only with borrowed light can never be ſeen at any very great diſtance. This conſideration brings us back to the ſun, as a refulgent fountain of light, whilſt it eſtabliſhes at the ſame time beyond a doubt that every ſtar muſt likewiſe be a ſun,

ſhining by its own native brightneſs. Here then we come to the more capital parts of the great conſtruction.

Theſe ſuns, every one of which is probably of as much conſequence to a ſyſtem of planets, ſatellites, and comets, as our own ſun, are now to be conſidered, in their turn, as the minute parts of a proportionally greater whole. I need not repeat that by my analyſis it appears, that the heavens conſiſt of regions where ſuns are gathered into ſeparate ſyſtems, and that the catalogues I have given comprehend a liſt of ſuch ſyſtems; but may we not hope that our knowledge will not ſtop ſhort at the bare enumeration of phænomena capable of giving us ſo much inſtruction? Why ſhould we be leſs inquiſitive than the natural philoſopher, who ſometimes, even from an inconſiderable number of ſpecimens of a plant, or an animal, is enabled to preſent us with the hiſtory of its riſe, progreſs, and decay? Let us then compare together, and claſs ſome of theſe numerous ſidereal groups, that we may trace the operations of natural cauſes as far as we can perceive their agency. The moſt ſimple form, in which we can view a ſidereal ſyſtem, is that of being globular. This alſo, very favourably to our deſign, is that which has preſented itſelf moſt frequently, and of which I have given the greateſt collection.

But, firſt of all, it will be neceſſary to explain what is our idea of a cluſter of ſtars, and by what means we have obtained it. For an inſtance, I ſhall take the phænomenon which preſents itſelf in many cluſters: It is that of a number of lucid ſpots, of equal luſtre, ſcattered over a circular ſpace, in ſuch a manner as to appear gradually more compreſſed towards the middle; and which compreſſion, in the cluſters to which I allude, is generally carried ſo far, as, by imperceptible degrees,

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to end in a luminous center, of a reſolvable blaze of light. To ſolve this appearance, it may be conjectured, that ſtars of any given, very unequal magnitudes, may eaſily be ſo arranged, in ſcattered, much extended, irregular rows, as to produce the above deſcribed picture; or, that ſtars, ſcattered about almoſt promiſcuouſly within the fruſtum of a given cone, may be aſſigned of ſuch properly diverſified magnitudes as alſo to form the ſame picture. But who, that is acquainted with the doctrine of chances, can ſeriouſly maintain ſuch improbable conjectures? To conſider this only in a very coarſe way, let us ſuppoſe a cluſter to conſiſt of 5000 ſtars, and that each of them may be put into one of 5000 given places, and have one of 5000 aſſigned magnitudes. Then, without extending our calculation any further, we have five and twenty millions of chances, out of which only one will anſwer the above improbable conjecture, while all the reſt are againſt it. When we now remark that this relates only to the given places within the fruſtum of a ſuppoſed cone, whereas theſe ſtars might have been ſcattered all over the viſible ſpace of the heavens; that they might have been ſcattered, even within the ſuppoſed cone, in a million of places different from the aſſumed ones, the chance of this apparent cluſter's not being a real one, will be rendered ſo highly improbable that it ought to be intirely rejected.

Mr. Michell computes, with reſpect to the ſix brighteſt ſtars of the Pleiades only, that the odds are near 500000 to 1 that no ſix ſtars, out of the number of thoſe which are equal in ſplendour to the fainteſt of them, ſcattered at random in the whole heavens, would be within ſo ſmall a diſtance from each other as the Pleiades are *.

* Phil. Tranſ. vol. LVII, p. 240.

Taking it then for granted that the ſtars which appear to be gathered together in a group are in reality thus accumulated, I proceed to prove alſo that they are nearly of an equal magnitude.

The cluſter itſelf, on account of the ſmall angle it ſubtends to the eye, we muſt ſuppoſe to be very far removed from us. For, were the ſtars which compoſe it at the ſame diſtance from one another as Sirius is from the ſun; and ſuppoſing the cluſter to be ſeen under an angle of 10 minutes, and to contain 50 ſtars in one of its diameters, we ſhould have the mean diſtance of ſuch ſtars twelve ſeconds; and therefore the diſtance of the cluſter from us about ſeventeen thouſand times greater than the diſtance of Sirius. Now, ſince the apparent magnitude of theſe ſtars is equal, and their diſtance from us is alſo equal,—becauſe we may ſafely neglect the diameter of the cluſter, which, if the center be ſeventeen thouſand times the diſtance of Sirius from us, will give us ſeventeen thouſand and twenty-five for the fartheſt, and ſeventeen thouſand wanting twenty-five for the neareſt ſtar of the cluſter;—it follows that we muſt either give up the idea of a cluſter, and recur to the above refuted ſuppoſition, or admit the equality of the ſtars that compoſe theſe cluſters. It is to be remarked that we do not mean intirely to exclude all variety of ſize; for the very great diſtance, and the conſequent ſmallneſs of the component cluſtering ſtars, will not permit us to be extremely preciſe in the eſtimation of their magnitudes; though we have certainly ſeen enough of them to know that they are contained within pretty narrow limits; and do not, perhaps, exceed each other in magnitude more than in ſome ſuch proportion as one full-grown plant of a certain ſpecies may exceed another full-grown plant of the ſame ſpecies.

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If we have drawn proper concluſions relating to the ſize of ſtars, we may with ſtill greater ſafety ſpeak of their relative ſituations, and affirm that in the ſame diſtances from the center an equal ſcattering takes place. If this were not the caſe, the appearance of a cluſter could not be uniformly encreaſing in brightneſs towards the middle, but would appear nebulous in thoſe parts which were more crowded with ſtars; but, as far as we can diſtinguiſh, in the cluſters of which we ſpeak, every concentric circle maintains an equal degree of compreſſion, as long as the ſtars are viſible; and when they become too crowded to be diſtinguiſhed, an equal brightneſs takes place, at equal diſtances from the center, which is the moſt luminous part.

The next ſtep in my argument will be to ſhew that theſe cluſters are of a globular form. This again we reſt on the ſound doctrine of chances. Here, by way of ſtrength to our argument, we may be allowed to take in all round nebulæ, though the reaſons we have for believing that they conſiſt of ſtars have not as yet been entered into. For, what I have to ſay concerning their ſpherical figure will equally hold good whether they be groups of ſtars or not. In my catalogues we have, I ſuppoſe, not leſs than one thouſand of theſe round objects. Now, whatever may be the ſhape of a group of ſtars, or of a Nebula, which we would introduce inſtead of the ſpherical one, ſuch as a cone, an ellipſis, a ſpheroid, a circle or a cylinder, it will be evident that out of a thouſand ſituations, which the axes of ſuch forms may have, there is but one that can anſwer the phænomenon for which we want to account; and that is, when thoſe axes are exactly in a line drawn from the object to the place of the obſerver. Here again we have a million of chances of which all but one are againſt any other

hypotheſis than that which we maintain, and which, for this reaſon, ought to be admitted.

The laſt thing to be inferred from the above related appearances is, that theſe cluſters of ſtars are more condenſed towards the center than at the ſurface. If there ſhould be a group of ſtars in a ſpherical form, conſiſting of ſuch as were equally ſcattered over all the aſſigned ſpace, it would not appear to be very gradually more compreſſed and brighter in the middle; much leſs would it ſeem to have a bright nucleus in the center. A ſpherical cluſter of an equal compreſſion within,—for that ſuch there are will be ſeen hereafter,—may be diſtinguiſhed by the degrees of brightneſs which take place in going from the center to the circumference. Thus, when $a$ is the brightneſs in the center, it will be $\sqrt{a^2 - x^2}$ at any other diſtance $x$ from the center. Or, putting $a = 1$, and $x =$ any decimal fraction; then, in a table of natural ſines, where $x$ is the ſine, the brightneſs at $x$ will be expreſſed by the coſine. Now, as a gradual encreaſe of brightneſs does not agree with the degrees calculated from a ſuppoſition of an equal ſcattering, and as the cluſter has been proved to be ſpherical, it muſt needs be admitted that there is indeed a greater accumulation towards the center. And thus, from the above-mentioned appearances, we come to know that there are globular cluſters of ſtars nearly equal in ſize, which are ſcattered evenly at equal diſtances from the middle, but with an encreaſing accumulation towards the center.

We may now venture to raiſe a ſuperſtructure upon the arguments that have been drawn from the appearance of cluſters of ſtars and nebulæ of the form I have been examining, which is that of which I have made mention in my "*Theoreti-*

"*eal view.—Formation of Nebulæ.—Form I.*" It is to be remarked that when I wrote the paragraph I refer to, I delineated nature as well as I do now; but, as I there gave only a general ſketch, without referring to particular caſes, what I then delivered may have been looked upon as little better than hypothetical reaſoning, whereas in the preſent inſtance this objection is intirely removed, ſince actual and particular facts are brought to vouch for the truth of every inference.

Having then eſtabliſhed that the cluſters of ſtars of the 1ſt Form, and round nebulæ, are of a ſpherical figure, I think myſelf plainly authorized to conclude that they are thus formed by the action of central powers. To manifeſt the validity of this inference, the figure of the earth may be given as an inſtance; whoſe rotundity, ſetting aſide ſmall deviations, the cauſes of which are well known, is without heſitation allowed to be a phænomenon deciſively eſtabliſhing a centripetal force. Nor do we ſtand in need of the revolving ſatellites of Jupiter, Saturn, and the Georgium Sidus, to aſſure us that the ſame powers are likewiſe lodged in the maſſes of theſe planets. Their globular figure alone muſt be admitted as a ſufficient argument to render this point uncontroventible. We alſo apply this inference with equal propriety to the body of the ſun, as well as to that of Mercury, Venus, Mars, and the Moon; as owing their ſpherical ſhape to the ſame cauſe. And how can we avoid inferring, that the conſtruction of the cluſters of ſtars, and nebulæ likewiſe, of which we have been ſpeaking, is as evidently owing to central powers?

Beſides, the ſtep that I here make in my inference is in fact a very eaſy one, and ſuch as ought freely to be granted. Have I not already ſhewn that theſe cluſters cannot have come to

* Phil. Tranſ. vol. LXXV, p. 214.

their

their preſent formation by any random ſcattering of ſtars? The doctrine of chance, by expoſing the very great odds againſt ſuch hypotheſes, may be ſaid to demonſtrate that the ſtars are thus aſſembled by ſome power or other. Then, what do I attempt more than merely to lead the mind to the conditions under which this power is ſeen to act?

In a caſe of ſuch conſequence I may be permitted to be a little more diffuſe, and draw additional arguments from the internal conſtruction of ſpherical cluſters and nebulæ. If we find that there is not only a general form, which, as has been proved, is a ſufficient manifeſtation of a centripetal force, what ſhall we ſay when the accumulated condenſation, which every where follows a direction towards a center, is even viſible to the very eye? Were we not already acquainted with attraction, this gradual condenſation would point out a central power, by the remarkable diſpoſition of the ſtars tending towards a center. In conſequence of this viſible accumulation, whether it may be owing to attraction only, or whether other powers may aſſiſt in the formation, we ought not heſitate to aſcribe the effect to ſuch as are *central*; no phænomena being more deciſive in that particular, than thoſe of which I am treating.

I am fully aware of the conſequences I ſhall draw upon myſelf in but mentioning other powers that might contribute to the formation of cluſters. A mere hint of this kind, it will be expected, ought not to be given without ſufficient foundation; but let it ſuffice at preſent to remark that my arguments cannot be affected by my terms: whether I am right to uſe the plural number,—central powers,—or whether I ought only to ſay,—the known central force of gravity,—my concluſions will be equally valid. I will however add, that the idea of other

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central powers being concerned in the conſtruction of the ſidereal heavens, is not one that has only lately occurred to me. Long ago I have entertained a certain theory of diverſified central powers of attractions and repulſions; an expoſition of which I have even delivered in the years 1780, and 1781, to the Philoſophical Society then exiſting at Bath, in ſeveral mathematical papers upon that ſubject. I ſhall, however, ſet aſide an explanation of this theory, which would not only exceed the intended limits of this paper, but is moreover not required for what remains at preſent to be added, and therefore may be given ſome other time, when I can enter more fully into the ſubject of the interior conſtruction of ſidereal ſyſtems.

To return, then, to the caſe immediately under our preſent conſideration, it will be ſufficient that I have abundantly proved that the formation of round cluſters of ſtars and nebulæ is either owing to central powers, or at leaſt to one ſuch force as refers to a center.

I ſhall now extend the weight of my argument, by taking in likewiſe every cluſter of ſtars or nebula that ſhews a gradual condenſation, or encreaſing brightneſs, towards a center or certain point; whether the outward ſhape of ſuch cluſters or nebulæ be round, extended, or of any other given form. What has been ſaid with regard to the doctrine of chance, will of courſe apply to every cluſter, and more eſpecially to the extended and irregular ſhaped ones, on account of their greater ſize: It is among theſe that we find the largeſt aſſemblages of ſtars, and moſt diffuſive nebuloſities; and therefore the odds againſt ſuch aſſemblages happening without ſome particular power to gather them, encreaſe exceedingly with the number of the ſtars that are taken together. But if the gradual accumulation either of ſtars or encreaſing brightneſs has before

been admitted as a direction to the ſeat of power, the ſame effect will equally point out the ſame cauſe in the caſes now under conſideration. There are beſides ſome additional circumſtances in the appearance of extended cluſters and nebulæ, that very much favour the idea of a power lodged in the brighteſt part. Although the form of them be not globular, it is plainly to be ſeen that there is a tendence towards ſphericity, by the ſwell of the dimenſions the nearer we draw towards the moſt luminous place, denoting as it were a courſe, or tide of ſtars, ſetting towards a center. And—if allegoral expreſſions may be allowed—it ſhould ſeem as if the ſtars thus flocking towards the ſeat of power were ſtemmed by the crowd of thoſe already aſſembled, and that while ſome of them are ſucceſsful in forcing their predeceſſors ſideways out of their places, others are themſelves obliged to take up with lateral ſituations, while all of them ſeem equally to ſtrive for a place in the central ſwelling, and generating ſpherical figure.

Since then almoſt all the nebulæ and cluſters of ſtars I have ſeen, the number of which is not leſs than three and twenty hundred, are more condenſed and brighter in the middle; and ſince, from every form, it is now equally apparent that the central accumulation or brightneſs muſt be the reſult of central powers, we may venture to affirm that this theory is no longer an unfounded hypotheſis, but is fully eſtabliſhed on grounds which cannot be overturned.

Let us endeavour to make ſome uſe of this important view of the conſtructing cauſe, which can thus model ſidereal ſyſtems. Perhaps, by placing before us the very extenſive and varied collection of cluſters, and nebulæ furniſhed by my catalogues, we may be able to trace the progreſs of its operation, in the great laboratory of the Univerſe.

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If theſe cluſters and nebulæ were all of the ſame ſhape, and had the ſame gradual condenſation, we ſhould make but little progreſs in this inquiry; but, as we find ſo great a variety in their appearances, we ſhall be much ſooner at a loſs how to account for ſuch various phænomena, than be in want of materials upon which to exerciſe our inquiſitive endeavours.

Some of theſe round cluſters conſiſt of ſtars of a certain magnitude, and given degree of compreſſion, while the whole cluſter itſelf takes up a ſpace of perhaps 10 minutes; others appear to be made up of ſtars that are much ſmaller, and much more compreſſed, when at the ſame time the cluſter itſelf ſubtends a much ſmaller angle, ſuch as 5 minutes. This diminution of the apparent ſize, and compreſſion of ſtars, as well as diameter of the cluſter to 4, 3, 2 minutes, may very conſiſtently be aſcribed to the different diſtances of theſe cluſters from the place in which we obſerve them; in all which caſes we may admit a general equality of the ſizes, and compreſſion of the ſtars that compoſe them, to take place. It is alſo highly probable that a continuation of ſuch decreaſing magnitudes, and encreaſing compreſſion, will juſtly account for the appearance of round, eaſily reſolvable, nebulæ; where there is almoſt a certainty of their being cluſters of ſtars. And no Aſtronomer can heſitate to go ſtill farther, and extend his ſurmiſes by imperceptible ſteps to other nebulæ, that ſtill preſerve the ſame characteriſtics, with the only variations of vaniſhing brightneſs, and reduction of ſize.

Other cluſters there are that, when they come to be compared with ſome of the former, ſeem to contain ſtars of an equal magnitude, while their compreſſion appears to be conſiderably different. Here the ſuppoſition of their being at different diſtances will either not explain the apparently greater

compreſſion, or, if admitted to do this, will convey to us a very inſtructive conſequence: which is, that the ſtars which are thus ſuppoſed not to be more compreſſed than thoſe in the former cluſter, but only to appear ſo on account of their greater diſtance, muſt needs be proportionally larger, ſince they do not appear of leſs magnitude than the former. As therefore, one or other of theſe hypotheſes muſt be true, it is not all improbable but that, in ſome inſtances, the ſtars may be more compreſſed; and in others, of a greater magnitude. This variety of ſize, in different ſpherical cluſters, I am however inclined to believe, may not go farther than the difference in ſize, found among the individuals belonging to the ſame ſpecies of plants, or animals, in their different ſtates of age, or vegetation, after they are come to a certain degree of growth. A farther inquiry into the circumſtance of the extent, both of condenſation and variety of ſize, that may take place with the ſtars of different cluſters, we ſhall poſtpone till other things have been previouſly diſcuſſed.

Let us then continue to turn our view to the power which is moulding the different aſſortments of ſtars into ſpherical cluſters. Any force, that acts uninterruptedly, muſt produce effects proportional to the time of its action. Now, as it has been ſhewn that the ſpherical figure of a cluſter of ſtars is owing to central powers, it follows that thoſe cluſters which, *ceteris paribus*, are the moſt compleat in this figure, muſt have been the longeſt expoſed to the action of theſe cauſes. This will admit of various points of views. Suppoſe for inſtance that 5000 ſtars had been once in a certain ſcattered ſituation, and that other 5000 equal ſtars had been in the ſame ſituation, then that of the two cluſters which had been longeſt expoſed to the action of the modelling power, we ſuppoſe,

would be moſt condenſed, and more advanced to the maturity of its figure. An obvious conſequence that may be drawn from this conſideration is, that we are enabled to judge of the relative age, maturity, or climax of a ſidereal ſyſtem, from the diſpoſition of its component parts; and, making the degrees of brightneſs in nebulæ ſtand for the different accumulation of ſtars in cluſters, the ſame concluſions will extend equally to them all. But we are not to conclude from what has been ſaid that every ſpherical cluſter is of an equal ſtanding in regard to abſolute duration, ſince one that is compoſed of a thouſand ſtars only, muſt certainly arrive to the perfection of its form ſooner than another, which takes in a range of a million. Youth and age are comparative expreſſions; and an oak of a certain age may be called very young, while a cotemporary ſhrub is already on the verge of its decay. The method of judging with ſome aſſurance of the condition of any ſidereal ſyſtem may perhaps not improperly be drawn from the ſtandard laid down page 218; ſo that, for inſtance, a cluſter or nebula which is very gradually more compreſſed and bright towards the middle, may be in the perfection of its growth, when another which approaches to the condition pointed out by a more equal compreſſion, ſuch as the nebulæ I have called *Planetary* ſeem to preſent us with, may be looked upon as very aged, and drawing on towards a period of change, or diſſolution. This has been before ſurmiſed, when, in a former paper, I conſidered the uncommon degree of compreſſion that muſt prevail in a nebula to give it a planetary aſpect; but the argument, which is now drawn from the powers that have collected the formerly ſcattered ſtars to the form we find they have aſſumed, muſt greatly corroborate that ſentiment.

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This method of viewing the heavens ſeems to throw them into a new kind of light. They now are ſeen to reſemble a luxuriant garden, which contains the greateſt variety of productions, in different flouriſhing beds; and one advantage we may at leaſt reap from it is, that we can, as it were, extend the range of our experience to an immenſe duration. For, to continue the ſimile I have borrowed from the vegetable kingdom, is it not almoſt the ſame thing, whether we live ſucceſſively to witneſs the germination, blooming, foliage, fecundity, fading, withering, and corruption of a plant, or whether a vaſt number of ſpecimens, ſelected from every ſtage through which the plant paſſes in the courſe of its exiſtence, be brought at once to our view?

WILLIAM HERSCHEL.

Slough near Windſor, May 1, 1789.

## Firſt Claſs. Bright nebulæ.

| I. | 1785 | Stars. | | M. | S. | | D.M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|
| 94 | April 28 | 61 Urſæ | f | 0 | 6 | n | 2 17 | 2 | cB. pL. E. ſp nf. vgmbM. $3\frac{1}{2}$ l. 2′b. |
| 95 | —— | —— | f | 35 | 0 | n | 2 7 | 2 | cB. cL. E. np ff. bM. 4′l. $3\frac{1}{2}$ b. |
| 96 | May 1 | 14 Canum | f | 5 | 30 | n | 1 12 | 2 | vB. cL. mE. ſp nf. ſmbM. 6′l. $1'\frac{1}{2}$ b. |
| 97 | —— | —— | f | 7 | 58 | n | 0 47 | 1 | vB. pL. E. nearly mer. gmbM. |
| 98 | —— | —— | f | 36 | 50 | f | 0 12 | 1 | cB. pL. R. vgmbM. |
| 99 | —— | 27 (γ) Bootis | p | 13 | 46 | f | 1 46 | 2 | vB. S. R. vſmbM. |
| 100 | Sept. 10 | 41 Ceti | f | 13 | 43 | n | 0 48 | 1 | cB. pS. R. mbM. See III. 431. |
| 101 | —— | 67 —— | p | 17 | 19 | n | 0 25 | 2 | cB. pL. E. near. mer. mbM. 5′ l. |
| 102 | —— | —— —— | f | 21 | 37 | f | 0 13 | 2 | cB. pL. R. mbM. |
| 103 | 24 | 14 Delphini | p | 16 | 10 | f | 0 3 | 1 | vB. L. gmbM. er. beautif. object. |
| 104 | 28 | 93 (π) Aquæ | f | 1 | 8 | n | 0 42 | 1 | cB. cL. E. near. mer. gmbM. F. rays. |
| 105 | Oct. 3 | 47 Ceti | f | 26 | 24 | f | 0 37 | 1 | cB. pL. iR. mbM. |
| 106 | —— | 89 (π) —— | f | 38 | 10 | f | 1 24 | 2 | cB cL. iR. bM. 3′ dia. |
| 107 | 6 | 20 Eridani | f | 4 | 3 | f | 1 4 | 2 | vR. R. BNM. $1'\frac{1}{2}$ dia. |
| 108 | 8 | 111 (ξ) Piſcⁱᵐ | p | 34 | 22 | f | 0 1 | 1 | cB. vL. iR. p. vBſt. |
| 109 | 26 | 12 Eridani | p | 7 | 17 | n | 2 54 | 3 | cB. pS. lE. mer. mbM. r. $1'\frac{1}{2}$ l. |

| I. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 110 | Nov. 27 | 9 Ceti | p | 44 | 0 | s | 0 | 47 | 2 | cB. cL. lE. gmbM. iF. |
| 111 | — | — — — | p | 43 | 3 | s | 0 | 6 | 2 | cB. cL. iR. gmbM. |
| 112 | 29 | 5(γ) Arietis | f | 5 | 48 | s | 0 | 17 | 1 | vB. L. R. mbM. not er. 4′ dia. |
| 113 | Dec. 7 | 60(4th σ)Can | f | 18 | 22 | n | 1 | 34 | 2 | cB. cL. lE. iF. mb foll. side. |
| 114 | — | 18 Leo. min. | p | 13 | 39 | s | 0 | 35 | 1 | cB. cL. iF. mbM. |
| 115 | — | — — — | p | 5 | 47 | n | 1 | 10 | 2 | cB. pL. lE. iF. mbM. |
| 116 | — | 37 — — | f | 11 | 5 | n | 1 | 1 | 1 | Two; the 1st, cB. cL. iE.; the 2d, pB. pL. iE. Dist. 1′ at the vertex. |
| 117 | | | | | | | | | | |
| 118 | — | 46 Ursæ | p | 3 | 41 | s | 1 | 32 | 1 | cB. cL. iR. mbM. |
| 119 | 28 | 31(1st d)Vir | p | 6 | 0 | n | 0 | 55 | 1 | vB. pS. |
| 120 | 31 | 30(π) Crateri | p | 9 | 0 | n | 0 | 17 | 1 | cB. L. iR. bM. 5′ l. 4′ b. |
| | 1786 | | | | | | | | | |
| 121 | Jan. 1 | 13(π) Virgin | p | 18 | 15 | s | 0 | 19 | 1 | vB. cL. lE. mbM. 3′ l. 2′ ½ b. bet. 2pBst. |
| 122 | Feb. 1 | 57(μ) Eridani | p | 4 | 0 | n | 0 | 22 | 1 | cB. vL. iR. bM. er. 5 or 6′ dia. |
| 123 | 2 | 60 (σ) Virg. | p | 52 | 27 | s | 0 | 30 | 2 | cB. S. |
| 124 | — | — — — | p | 39 | 57 | s | 0 | 3 | 2 | cB. cL. R. |
| 125 | — | — — — | p | 39 | 12 | s | 1 | 0 | 2 | cB. cL. E. mbM. |
| 126 | 24 | 108 — | p | 0 | 35 | n | 1 | 15 | 1 | eB. mE. par. BN. 8 or 9′ l. |
| 127 | — | 110 — | p | 1 | 47 | s | 0 | 23 | 1 | cB. pS. mbM. |
| 128 | — | — — | f | 3 | 37 | s | 0 | 30 | 1 | vB. pL. bM. |
| 129 | March 3 | 26 (χ) — | f | 9 | 46 | s | 0 | 41 | 1 | v brilliant. iR. vgmbM. |
| 130 | — | — — — | f | 26 | 35 | s | 0 | 3 | 2 | vB. lE. mer. BN. and F. br. 2′ l. |
| 131 | 4 | 14 (ε) Crate. | f | 0 | 29 | n | 1 | 3 | 1 | cB. E. gbM. 5′ l. 4′ b. |
| 132 | 19 | 26 Hydræ | f | 1 | 44 | n | 0 | 4 | 2 | cB. pL. lE. vgbM. 1′ ¼ diam. |
| 133 | 25 | 49(g) Virgin. | p | 16 | 4 | n | 0 | 18 | 1 | cB. vS. BN. |
| 134 | — | — — — | p | 13 | 27 | n | 0 | 13 | 1 | eB. 7 or 8′ l. 3′ b. |
| 135 | — | 68 (ι) — | p | 32 | 2 | n | 0 | 11 | 2 | Two; both cB. cS. R. mbM. |
| 136 | 27 | | | | | | | | | Dist. 1′ near. mer. chev. mixed. |
| 137 | 28 | 41 Lyncis. | f | 3 | 13 | n | 0 | 8 | 1 | vB. R. vsmbM. chev. 3′ dia. |
| 138 | — | *1102 (ε) Hy | f | 33 | 45 | n | 1 | 27 | 1 | cB. R. psmbM. *See note. |
| 139 | April 17 | 11 (s) Virgin. | f | 12 | 1 | s | 1 | 21 | 2 | eB. vBN. r. 6 or 7′ dia. |
| 140 | — | — — — | f | 39 | 55 | s | 0 | 31 | 2 | cB. pL. mbM. |
| 141 | — | — — — | f | 45 | 50 | s | 1 | 32 | 1 | vB. cL. E. np ff. |
| 142 | 30 | 37 — | p | 6 | 35 | n | 0 | 0 | 1 | cB. pL. iR. gmbM. |
| 143 | — | 43 (β) Virgin | f | 4 | 55 | s | 2 | 7 | 1 | cB. np. pBst. and close to it. |
| 144 | — | 109 — | p | 25 | 58 | n | 0 | 54 | 1 | cB. cL. R. gmbM. |
| 145 | — | — — — | p | 25 | 14 | n | 1 | 27 | 1 | Two; the p. pB. pL. E. Dist. 30 or 4′ sp nf. Thef. cB. R. pL. Place of 2d. |
| 146 | | | | | | | | | | |
| 147 | — | 43 Ophiuchi | p | 8 | 54 | s | 1 | 17 | 1 | vB. R. gmbM. 2′ ½ dia. |
| 148 | May 1 | 24 (ω) Serpen | p | 22 | 26 | s | 1 | 16 | 1 | cB. cL. iR. bM. |
| 149 | 28 | 40 (ε) Ophiu | f | 0 | 14 | n | 1 | 32 | 1 | cB. pS. lE. er. |
| 150 | — | — — — | f | 27 | 53 | n | 0 | 36 | 1 | cB. R. vgmbM. about 1′ ½ dia. |
| 151 | Sept. 4 | 71 (ι) Piscium | f | 21 | 41 | n | 1 | 41 | 1 | cB. cL. R. C. vgmbM. N. |
| 152 | — | 24 (ξ) Arietis | p | 16 | 23 | n | 0 | 20 | 2 | vB. vS. R. or lE. vBN. 1′ ff. est |

| I. | 1786 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 153 | Sept. 20 | 59 (2d υ) Ceti | p | 23 | 16 | f | 0 | 6 | 1 | cB. vL. E. sp nf. above 15′ l. |
| 154 | 21 | 14 Triang. | f | 1 | 23 | n | 0 | 59 | 2 | cB pL. E. np sf. vgmbM. 3′ l. 2′ b. |
| 155 | 30 | 32 Eridani | f | 7 | 49 | f | 1 | 1 | 2 | cB. S. gmbM. |
| 156 | Oct. 18 | 12 (q) Persei | p | 1 | 41 | f | 1 | 10 | 2 | cB. mE. 12° sp nf. vBN. near 10′ l. |
| 157 | 26 | 90 (υ) Piscium | f | 28 | 9 | n | 0 | 13 | 1 | cB. cL. E. par. mbM. 7′ l. 3′ b. |
| 158 | Nov. 26 | 48 (ι) Eridani | p | 4 | 32 | f | 1 | 46 | 2 | cB. pL. iR. vgmbM. |
| 159 | Dec. 11 | 20 (π) Cassiop. | f | 8 | 30 | n | 0 | 33 | 3 | vB. R. vgbM. 1′½ dia. |
| 160 | 29 | 29 (γ) Virgin | p | 6 | 17 | f | 2 | 19 | 2 | vB. cL. E. sp nf. vgBN. F. bran. |
| | 1787 | | | | | | | | | |
| 161 | Jan. 14 | 6 Cornæ | f | 12 | 58 | f | 0 | 55 | 1 | vB. pL. iR. |
| 162 | — | 29 —— | f | 10 | 35 | n | 0 | 2 | 1 | vB. E. sp nf. Sst in it ½′ p. N. |
| 163 | Feb. 22 | 20 Sextantis | p | 8 | 29 | f | 0 | 22 | 1 | cB. cL. mE. 45 sp nf. N. 2′ l. F. br. 5′ l. |
| 164 | Mar. 17 | 38 Leo. min. | p | 2 | 54 | f | 0 | 36 | 3 | cB. E. 30° np sf. mbM. er. 4′ l. 2′ b. |
| 165 | — | 6 Canum | p | 15 | 42 | n | 0 | 25 | 2 | vB. BN. not M. or 2 joined the n. N. |
| 166 | — | — —— | p | 1 | 20 | n | 0 | 23 | 2 | vB. S. R. mbM. |
| 167 | 18 | 10 (π) Ursæ | f | 13 | 43 | f | 1 | 40 | 1 | cB. R. BN. 1′½ dia. |
| 168 | — | 34 (μ) —— | p | 4 | 9 | f | 0 | 6 | 3 | cB. R. vgbM. 8′ dia. cst. in it, unconnected. |
| 169 | — | 6 Canum | p | 16 | 16 | n | 0 | 53 | 1 | cB. cL. |
| 170 | — | 20 —— | f | 28 | 12 | n | 1 | 6 | 2 | cB. E. near par. SNM. 2′ l. |
| 171 | — | 53 (2d ι) Boot | p | 49 | 57 | n | 1 | 10 | 2 | cB. S. R. r. mbM. |
| 172 | 19 | 31 Leo. min. | f | 25 | 2 | f | 0 | 3 | 1 | cB. E. sp nf. few st. in p. 1 in n. unconnected. |
| 173 | — | — — — | f | 86 | 19 | n | 0 | 23 | 1 | vB. R. vgNM. 2′½ dia. |
| 174 | 20 | 53 (ξ) Ursæ | f | 46 | 14 | n | 0 | 24 | 1 | cB. E. 5′ l. 1′½ b. |
| 175 | — | 13 Canum | p | 46 | 3 | n | 2 | 28 | 1 | vB. S R. mbM. |
| 176 } 177 } | — | — —— | p | 16 | 33 | n | 1 | 26 | 1 | Two. The f. cB. E. mbM. The n. pB. E. sp nf. Both join and form the letter S. |
| 178 } 179 } | April 9 | 8 —— | f | 7 | 36 | f | 0 | 12 | 1 | Two. The n. vB. vmbM. The f. pB. Their nebul. run together. |
| 180 | — | 20 —— | f | 29 | 9 | n | 3 | 15 | 1 | cB. mE. 60° np ff. vfBM. |
| 181 | — | — —— | f | 40 | 13 | n | 1 | 11 | 1 | cB. cL. mbM. |
| 182 | 11 | 1 Serpentis | p | 17 | 22 | f | 0 | 2 | 2 | cB. pL. iR. mbM. |
| 183 | — | — —— | p | 11 | 19 | n | 0 | 1 | 2 | cB. pL. iR. or lE. |
| 184 | May 7 | 8 Libræ | p | 8 | 21 | f | 1 | 15 | 1 | cB. pL. E. sp nf. mbM. |
| 185 | 11 | 19 (λ) Bootis | f | 11 | 6 | n | 0 | 1 | 2 | c or pB S. R. pmbM. |
| 186 | 12 | — — —— | p | 47 | 14 | n | 1 | 20 | 2 | cB. pL. R or lE. vgbM. 3′ np. the 51st of the *Conn. des Temps.* |
| 187 | — | — — —— | p | 20 | 15 | n | 1 | 14 | 1 | cB. E. 30 sp nf. BN. vgF. branches. |
| 188 | — | 38 (2d b) —— | p | 13 | 24 | n | 2 | 44 | 2 | cB. lE. par. mbM. F. bran. 1′½ l. |
| 189 | 15 | 24 (g) —— | f | 3 | 57 | f | 0 | 23 | 1 | cB. cL. E. sp nf. broad. |

| I. | 1787 | Stars. | | M. | S. | | D.M. | | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 190 | May 16 | *Canum 6m. | f | 11 | 32 | ſ | 1 | 11 | 1 | Two. The ſ. cB. cL. The n, pB. |
| 191 | | | | | | | | | | S. diſt. 1′¼. * See note. |
| 192 | Oct. 14 | 3 Lacertæ | p | 80 | 46 | n | 2 | 32 | 3 | cB. iF. 3′ l. 2′¼ b. Nebuloſity. |
| 193 | Nov. 12 | 54 (φ) Andro | p | 1 | 26 | n | 0 | 54 | 1 | Two cloſe together. BothvB. diſt. 2′. ſp nf. One is 76 of the *Conn.* |
| | 1788 | | | | | | | | | |
| 194 | Jan. 14 | 56 Urſæ | f | 3 | 19 | n | 0 | 5 | 2 | vB. cL. mE. mer. BN. 6′ l, 2′ b, chev. |
| 195 | — | 67 —— | f | 4 | 49 | n | 0 | 2 | 2 | E. vBN. and F. branches. |
| 196 | — | —— —— | f | 7 | 17 | n | 0 | 38 | 2 | cB. cL. iF. vgbM. ff. ſt. |
| 197 | — | 8 Canum | p | 3 | 32 | n | 0 | 19 | 1 | Two. The ſ. vB. vL. iE. The |
| 198 | | | | | | | | | | n. B. pS. iF. diſt. 1′¼. |
| 199 | 15 | 15 Leo. min. | f | 32 | 1 | ſ | 0 | 24 | 2 | cB. mE. ſp nf. vgbM. 5′ l. 2 or 3′ b. |
| 200 | Feb. 5 | 59 (2d σ) Can | p | 4 | 29 | n | 0 | 29 | 1 | v brilliant. mE. ſp nf. 8′ l. 3′ b. beauti. |
| 201 | — | 63 (χ) Urſæ | f | 0 | 5 | f | 0 | 17 | 2 | cB. mE. ſp nf. near. mer. 5′ l. 1′ b. |
| 202 | — | —— —— —— | f | 0 | 47 | n | 0 | 4 | 2 | cB. S. lE. |
| 203 | 6 | 59 —— | f | 7 | 42 | n | 0 | 31 | 1 | cB. cL. R. pBNM. |
| 204 | March 9 | 9 (ι) —— | p | 16 | 27 | n | 2 | 7 | 1 | cB. vS. lE. m. |
| 205 | — | —— —— —— | f | 22 | 18 | n | 3 | 1 | 1 | vB. lbM. chev. b an. m. neb. 6′ l. 4′ b. |
| 206 | — | 3 Canum | p | 14 | 39 | n | 1 | 35 | 3 | cB. E. 45° np ff. 6′ l. 4′ b. almoſt equally B. |
| 207 | — | —— —— | p | 14 | 0 | ſ | 1 | 32 | 3 | cB. mE. 70° ſp nf. 6 or 7′ l. 2′ b. |
| 208 | — | —— —— | p | 9 | 9 | n | 1 | 32 | 3 | cB. mE. ſp nf. SBNM. 5′ l. 1′ b. |
| 209 | — | —— —— | p | 3 | 33 | ſ | 1 | 6 | 2 | cB. cL. E. mbM. |
| 210 | April 1 | 60 Urſæ | f | 46 | 0 | n | 0 | 9 | 2 | vB. S. lE. near. par. BN. eF. bran. |
| 211 | — | 11 Canum | f | 5 | 47 | ſ | 1 | 58 | 3 | cB. S. R. bM. f. vSſt. |
| 212 | 10 | 60 Urſæ | f | 50 | 50 | ſ | 1 | 58 | 1 | cB. pL. E. |
| 213 | 27 | 19 (λ) Bootis | p | 110 | 25 | ſ | 1 | 48 | 1 | v brilliant. eL. E. ſp nf. difficulty r. has 3 or 4 BN. |
| 214 | May 1 | 17 (κ) —— | p | 8 | 26 | n | 1 | 56 | 1 | cB. cL. n. ends abruptly. ſ. vg. |
| 215 | 5 | Neb. II. 757. | p | 3 | 27 | ſ | 1 | 14 | 1 | vB. cL. E. f. 2 ſt. |

## Second claſs. Faint nebulæ.

| II. | 1785 | Stars. | | M. | S. | | D.M. | | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 403 | April 26 | 1 Comæ | p | 8 | 50 | ſ | 1 | 21 | 3 | F. cL. iF. lbM. |
| 404 | 27 | 5 —— | p | 11 | 40 | ſ | 0 | 29 | 1 | pB. pL. R. C. mbM. |
| 405 | — | —— —— | p | 1 | 0 | ſ | 0 | 24 | 2 | pB. pL. iF. lE. bM. p. pcſt. |
| 406 | — | 20 —— | p | 6 | 8 | ſ | 1 | 27 | 1 | pF. pL. mbM. S neb. joined to it. or lb. in the n. |
| 407 | — | —— —— | f | 6 | 44 | ſ | 1 | 35 | 1 | pB. pS. lE. |
| 408 | 28 | 61 Urſæ | f | 7 | 54 | n | 0 | 46 | 2 | F. S. R. gbM. near ¼′ dia. |
| 409 | May 1 | — —— | f | 33 | 54 | n | 2 | 25 | 2 | pB. pL. vgbM. r. |
| 410 | — | 14 Canum | p | 32 | 8 | ſ | 0 | 14 | 2 | pB. cL. R. ſmbM. r. |

| II. | 1785 | Stars. | | M. | S. | | D.M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|
| 411 | May 1 | 14 Canum | p | 24 | 25 | f | 0 43 | 2 | pB. pL. R. lbM. 2′ np. pBſt. |
| 412 | — — | — — | p | 17 | 8 | f | 0 28 | 2 | F. S. lE. glbM. cr. |
| 413 | — — | — — | p | 0 | 50 | f | 0 36 | 2 | pB. S. R. bM. and vlF. on the edges. |
| 414 | — — | — — | f | 5 | 58 | n | 0 27 | 1 | F. S. lE. |
| 415 | — — | — — | f | 48 | 34 | n | 0 15 | 1 | F. S. iF. |
| 416 | — — | — — | f | 58 | 10 | f | 1 8 | 2 | pB. pL. iE. mbM. |
| 417 | — — | — — | f | 38 | 18 | f | 0 47 | 1 | pB. pL. iE. bM. |
| 418 | — | 51 (μ) Bootis | p | 69 | 38 | f | 1 48 | 1 | pB. iR. mbM. |
| 419 | — — | — — | p | 68 | 31 | f | 0 37 | 1 | F. pL. |
| 420 | — — | — — | p | 61 | 32 | f | 2 17 | 1 | pB. vS. R. vgmbM. |
| 421 | — — | — — | p | 55 | 14 | f | 1 53 | 1 | F. pL. iF. |
| 422 | — — | — — | p | 52 | 36 | f | 0 52 | 1 | F. cL. iF. unequally. B. |
| 423 | — — | — — | p | 47 | 57 | f | 0 37 | 1 | pF. pS. iF. bM. |
| 424 | 2 | 49 (ϑ) — | p | 83 | 12 | n | 0 31 | 1 | F. pL. lbM. |
| 425 | 5 | 34 (ν) Serpen | p | 4 | 0 | n | 0 15 | 3 | F. cS. iR. ſtellar. |
| 426 | Aug. 12 | 1 Aquarii | f | 7 | 50 | f | 0 12 | 1 | Two. The p. F. S. iR. mbM. The f. vF. vS. lbM. 3 or 4′ diſt. Place of 1ſt. |
| 427 | | | | | | | | | |
| 428 | 30 | 35 Pegaſi | f | 6 | 22 | n | 0 47 | 2 | pB. S. iR. lbM. r. |
| 429 | — | 6 (γ) Piſcium | p | 2 | 16 | n | 1 14 | 1 | Two. The f. pB. mE. par. mbM. 4′ l. 1′ b. The p. vF. cS 3 or 4′ diſt. and p. |
| 430 | | | | | | | | | |
| 431 | Sept. 10 | 92 (χ) Aqua | f | 2 | 0 | n | 0 9 | 2 | pB. S. lE. par. vgF. NM. 1′ l. |
| 432 | — — | — — | f | 22 | 5 | n | 1 9 | 4 | pB. cL. E. 75° ſp nf. 3′ l. |
| 433 | — | 41 Ceti | p | 18 | 0 | f | 0 4 | 1 | pB. pL. bM. i. parallelogram. mer. |
| 434 | — — | — — | p | 14 | 23 | n | 1 18 | 1 | F. S. iF. bM. r. |
| 435 | — | 67 — | p | 15 | 52 | f | 0 27 | 1 | F. S. iR. bM. |
| 436 | — — | — — | f | 1 | 45 | f | 0 14 | 1 | F. pS. lE. ſ. 2 or 3 uneq. ſt. |
| 437 | — — | — — | f | 2 | 7 | f | 0 24 | 1 | F. pS. lE. |
| 438 | — — | — — | f | 4 | 33 | n | 0 54 | 2 | pB. vL. iF. mbM. r. |
| 439 | 26 | 59 (ρ) Pegaſi | f | 8 | 34 | f | 0 30 | 1 | pB. pS. mbM. |
| 440 | — — | — — | f | 9 | 1 | f | 0 30 | 1 | pB. pS. bM. |
| 441 | — — | — — | f | 10 | 1 | n | 0 10 | 1 | F. S. |
| 442 | Oct. 1 | 62 (ι) Aqua | f | 9 | 4 | f | 0 5 | 3 | F. S. r. lbM. or f. M. |
| 443 | — — | — — | f | 15 | 19 | f | 1 29 | 2 | F. S. iR. lbM. 1′½ f. S. ſt. |
| 444 | — | 20 Ceti | p | 10 | 20 | f | 0 24 | 1 | F. pL. lbM. |
| 445 | — — | — — | p | 6 | 50 | f | 0 35 | 1 | F. iF. cr. 1′ b. |
| 446 | — — | — — | p | 2 | 16 | f | 0 45 | 2 | pB. S. R. mbM. m. |
| 447 | — | 34 — | f | 1 | 3 | n | 2 0 | 2 | F. S. Two more near it. See III. 592. 593. |
| 448 | — | 43 — | f | 3 | 28 | f | 0 53 | 1 | Two. Both ſtellar. within 1′ diſt. Nebuloſities run together. |
| 449 | | | | | | | | | |
| 450 | 3 | 71 (1ſt τ) Aqu | f | 11 | 10 | n | 0 45 | 2 | Two Both F. S. lE. different directions. cr. 2 or 3′ from each other. |
| 451 | | | | | | | | | |
| 452 | — | 18 Ceti | p | 5 | 33 | f | 0 59 | 1 | pB. pS. mbM. r. ſt. 1′½ diſt. |
| 453 | 5 | 63 (κ) Aqua | f | 13 | 50 | f | 1 19 | 1 | F. pL. E. par. r. |

| II. | 1785 | Stars. | | M. | S. | | D. | M. | Obſ | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 454 | Oct. 5 | 90 (φ) Aqua | f | 3 | 11 | n | 1 | 17 | 1 | F. S. almoſt ſtellar. |
| 455 | | 17 Eridani | f | 11 | 19 | n | 0 | 26 | 2 | Two. The p. pB. cL. E. lbM. |
| 456 | | | f | 11 | 46 | | 0 | 25 | | The f. eF. vS. E. |
| 457 | | 61 (ω) | p | 4 | 31 | f | 0 | 2 | 2 | F. cL. lbM. |
| 458 | 6 | 20 | f | 8 | 52 | f | 0 | 46 | 1 | pB. R. bM. |
| 459 | | | f | 9 | 14 | f | 1 | 4 | 1 | F. R. lbM. |
| 460 | | | f | 12 | 7 | n | 1 | 6 | 1 | pB. S. lE. mbM. N. |
| 461 | 8 | 111 (ξ) Piſciu | p | 28 | 48 | f | 1 | 32 | 3 | F. pL. iR. vgbM. 1′½ dia. |
| 462 | | | p | 27 | 52 | f | 1 | 32 | 2 | pB. R. vgbM. 1′½ dia. |
| 463 | | | p | 16 | 40 | f | 1 | 15 | 3 | F. S. ilE. par. mbM. |
| 464 | | 44 Eridani | p | 9 | 2 | n | 0 | 0 | 1 | F. vS. r. |
| 465 | 9 | 82 (∂) Ceti | f | 7 | 12 | f | 0 | 34 | 3 | F. pL. iR. lbM. |
| 466 | | | f | 7 | 4 | f | 0 | 49 | 3 | pB. cL. iR. mbM. |
| 467 | 25 | 7 (δ) Piſcium | p | 4 | 23 | n | 1 | 22 | 1 | pB. pL. iF. |
| 468 | 26 | | f | 0 | 11 | f | 1 | 10 | 1 | F. pL. iF. r. |
| 469 | 26 | 49 Aquarii | f | 5 | 14 | f | 0 | 4 | 1 | F. pS. lE er. ſome of the ſt. viſible. |
| 470 | Nov. 22 | 67 Ceti | f | 37 | 51 | f | 3 | 27 | 2 | pB. S. ſtellar. |
| 471 | 23 | 34 Piſcium | f | 20 | 53 | f | 0 | 55 | 1 | F. iF. lbM. |
| 472 | 27 | 18 Ceti | f | 2 | 18 | n | 1 | 24 | 1 | F. pS. |
| 473 | | 47 | f | 6 | 3 | n | 0 | 54 | 1 | F. S. iF. er. ſome of the ſt. viſible. |
| 474 | | 72 (ε) | p | 9 | 28 | n | 0 | 56 | 2 | pB. pL. lE. lbM. |
| 475 | | 83 (ι) | f | 24 | 23 | f | 0 | 3 | 1 | pF. pL. iF. bM. |
| 476 | 28 | 58 Aquarii | f | 2 | 43 | n | 0 | 31 | 1 | F. pL. iR. lbM. |
| 477 | | 70 | p | 2 | 28 | f | 0 | 27 | 1 | pB. pL. iR. lbM. |
| 478 | | 17 Ceti | p | 10 | 10 | n | 0 | 53 | 1 | pB. L. lE. lbM. |
| 479 | | | p | 5 | 13 | n | 1 | 35 | 1 | pB. mE. mer. 2′ l. |
| 480 | | | p | 2 | 34 | n | 0 | 34 | 1 | F. pL. lE. lbM. |
| 481 | | 53 (χ) | p | 0 | 24 | n | 0 | 23 | 1 | pB. cL. R. 1′½ f. S. |
| 482 | | 55 (1ſtξ) | f | 17 | 54 | n | 0 | 15 | 1 | Four. The p. 2, both F. E. S. |
| 483 | | | | | | | | | | within 1′ diſt. par. |
| 484 | | | f | 17 | 56 | n | 0 | 11 | 1 | Thef. two, both pF. pS. E. about |
| 485 | | | | | | | | | | 2′ diſt. and nearly mer. |
| 486 | | | f | 20 | 13 | n | 1 | 5 | 1 | F. S. E. |
| 487 | | | f | 37 | 18 | f | 0 | 7 | 1 | F. cL. iF. lbM. |
| 488 | | | f | 49 | 13 | f | 0 | 50 | 1 | F. S. iF. bM. |
| 489 | 29 | 23 (2d θ) Arie | f | 8 | 36 | n | 0 | 42 | 1 | F. S. lE. contains 3 ſt. uncon. |
| 490 | Dec. 7 | 66 (4 σ) Canc | f | 8 | 10 | n | 0 | 54 | 1 | pF. mE. r. 3′ l. 1′½ b. |
| 491 | | 18 Leo. min. | p | 13 | 13 | f | 0 | 30 | 1 | pB. pL. iF. lbM. |
| 492 | | | f | 1 | 47 | n | 0 | 0 | 1 | pB. pL. lE. near par. |
| 493 | | 37 | f | 13 | 7 | n | 0 | 49 | 1 | F. S. |
| 494 | | 46 Urſæ | p | 3 | 47 | f | 0 | 36 | 1 | pB. pL. iR. |
| 495 | 28 | 3 Leonis | f | 3 | 34 | n | 0 | 16 | 1 | F. pL. E. iF. |
| 496 | | 9 (ι) Virgin | f | 11 | 52 | f | 1 | 5 | 1 | F. |
| 497 | | 31 (ſt d) | p | 14 | 27 | n | 1 | 25 | 1 | pF. vS. |

| II. | 1785 | Stars. | M. | S. | | D.M. | Ob | | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|
| 498 | Dec. 28 | 31 (1ſt *d*) Vir | p | 12 | 30 | n 1 | 3 | 1 | F. pL. |
| 499 | | — — — | p | 10 | 55 | n 1 | 18 | 1 | F. |
| 500 | | — — — | p | 7 | 43 | n 1 | 24 | 1 | vL. er. ſome ſt. viſible. |
| 501 | | 30 52 (τ) Ceti | f | 4 | 36 | n 1 | 1 | 1 | F. S. R. vSpRN. |
| 502 | | — 76 (σ) — | f | 29 | 37 | n 0 | 30 | 1 | F. eS. ſtellar. p. pBſt. |
| 503 | | — — — | f | 31 | 37 | ſ 0 | 15 | 1 | pB. S. iF. mbM. |
| 504 | | — 20 Eridani | p | 30 | 24 | n 1 | 44 | 1 | pB. S. lE. mbM. |
| 505 | | 31 9 Hydræ | f | 34 | 16 | ſ 0 | 15 | 1 | pB. S. lE. ſp nf. ſmbM. |
| 506 | | — — — | f | 49 | 32 | ſ 0 | 37 | 1 | pB. S. lE. lb ffM. |
| 507 | | — 4 (ι) Crater | f | 13 | 25 | ſ 0 | 3 | 1 | F. S. E. |
| 508 | | — 30 (π) — | f | 4 | 26 | ſ 0 | 41 | 1 | pB. S. lE. bM. |
| 509 | | — — — | f | 6 | 52 | n 0 | 46 | 1 | F. cL. iR. lbM. |
| 510 | | — 53 Virginis | f | 2 | 58 | ſ 0 | 25 | 1 | F. lE. 1′½ l. |
| 511 | | — — — | f | 3 | 21 | ſ 0 | 12 | 2 | pB. pL. R. bM. |
| 512 | | — — — | f | 3 | 55 | ſ 0 | 12 | 2 | F. S. |
| 513 | | — — — | f | 4 | 53 | ſ 0 | 27 | 2 | pB. pL. iF. mbM. |
| | 1786 | | | | | | | | |
| 514 | Jan. 1 | 49 Eridani | p | 0 | 34 | ſ 1 | 9 | 1 | F. pL. E. ſp nf. 2′ l. 1′ b. |
| 515 | | — — — | f | 2 | 57 | ſ 1 | 33 | 1 | F. or pB. S. bM. |
| 516 | | — — — | f | 21 | 45 | ſ 1 | 16 | 1 | F. S. iR. lbM. |
| 517 | | — 29 (γ) Virgin | f | 19 | 8 | n 1 | 22 | 2 | pB. pL. R. bM. |
| 518 | 2 | 13 Canum | p | 44 | 34 | n 2 | 49 | 2 | Two. The p. F. S. E. The f. F. |
| 519 | | | p | 44 | 31 | 2 | 51 | | S. E. in a different direction. |
| 520 | 27 | 7 (ν) Hydræ | f | 24 | 25 | n 0 | 7 | 2 | F. S. lE. par. er. |
| 521 | | — 77 (σ) Leonis | p | 3 | 42 | ſ 1 | 28 | 3 | F. vS. iF. ſmbM. er. |
| 522 | 30 | 47 Eridani | f | 6 | 29 | ſ 0 | 21 | 1 | F. pS. iE. r. 1′ ſp. Sſt. |
| 523 | | — — — | f | 10 | 15 | ſ 0 | 17 | 1 | F. vS. iR. bM. almoſt ſtellar. |
| 524 | Feb. 1 | 57 (μ) — | p | 9 | 24 | n 0 | 3 | 1 | F. S. iF. lbM. p. a Sſt. |
| 525 | | — — — | p | 4 | 5 | n 1 | 27 | 1 | F. pL. lE. |
| 526 | | — — — | f | 0 | 16 | n 0 | 51 | 1 | F. cS. R. lbM. |
| 527 | | — — — | f | 7 | 30 | n 0 | 12 | 2 | pB. S. |
| 528 | | — — — | f | 7 | 40 | n 0 | 12 | 1 | F. S. lbM. |
| 529 | | — 28 (A) Hydr | p | 26 | 37 | n 0 | 8 | 1 | F. S. |
| 530 | | 2 60 (ρ) Virg | p | 52 | 32 | n 0 | 19 | 1 | E. S. |
| 531 | | — — — | p | 47 | 19 | ſ 1 | 12 | 2 | pB. pL. E. b. ſ. M. 3′ l. |
| 532 | | — — — | p | 35 | 12 | ſ 1 | 28 | 2 | F. pL. lbM. |
| 533 | | — 64 — | f | 26 | 8 | ſ 1 | 17 | 2 | F. pL. vlbM. 6 or 7′ l. 4′ b. |
| 534 | | — — — | f | 34 | 2 | ſ 0 | 15 | 2 | pB. vL. glbM. |
| 535 | | 24 10 (ν) — | f | 43 | 43 | ſ 0 | 39 | 1 | F. mE. np ff. 2′ l. ½ b. |
| 536 | | — — — | f | 48 | 21 | ſ 0 | 21 | 1 | pB. mE. mbM. 2′½ l. 1′ b. |
| 537 | | — 92 — | p | 46 | 53 | n 0 | 43 | 1 | F. pL. iR. er. |
| 538 | | — 108 — | p | 1 | 8 | n 0 | 59 | 1 | pB. cL. iR. |
| 539 | | — 110 — | p | 2 | 58 | ſ 0 | 11 | 1 | pB. cL. lE. gbM. |
| 540 | | — — — | f | 1 | 11 | ſ 0 | 53 | 1 | pB. S. mbM. |
| 541 | | — — — | f | 2 | 31 | ſ 0 | 28 | 1 | F. |

542

| H. | 1786 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 542 | Feb. 24 | 110 Virg | f | 2 | 31 | n | 0 | 0 | 1 | pB. |
| 543 | — | — — | f | 4 | 14 | f | 0 | 34 | 1 | F. |
| 544 | — | — — | f | 4 | 52 | n | 0 | 27 | 2 | pB. vS. |
| 545 | — | — — | f | 6 | 51 | f | 1 | 39 | 4 | pB. S. iE. lbM. |
| 546 | Mar. 3 | 6 (*b*) Leonis | p | 6 | 16 | n | 1 | 42 | 1 | Two. Both F. S. The place inaccurate in RA. |
| 547 | | | | | | | | | | |
| 548 | — | 14 Virginis | p | 10 | 27 | f | 0 | 8 | 1 | F. pL. mE. np ff. but near. par. |
| 549 | — | 26 (*x*) — | f | 17 | 34 | f | 0 | 33 | 1 | pB. vL. iF. lbM. |
| 550 | 4 | 14 (*ι*) Crate | p | 4 | 13 | n | 0 | 35 | 2 | Two. Both F. S. lbM. cBſt. between, but 1′¼ ſ. of them. |
| 551 | | | | 4 | 0 | | 0 | 36 | | |
| 552 | — | 21 (*θ*) — | p | 2 | 24 | f | 0 | 2 | 1 | F. pS. iR. f. vSſt. |
| 553 | — | — — — | f | 11 | 21 | f | 1 | 9 | 2 | pB. pL. iF. gbM. ſp. is Sſt. |
| 554 | 18 | 1 Cancri | f | 4 | 36 | f | 0 | 4 | 2 | pB. pL. er. vgmbM. |
| 555 | 19 | 26 Hydræ | f | 7 | 26 | n | 0 | 21 | 2 | pB. pL. iR. b. ſ. M. |
| 556 | 20 | 6 (3d *b*) Crat | p | 76 | 10 | f | 1 | 11 | 3 | pB. cL. iR vgmbM. |
| 557 | 24 | 16 (*ζ*) Hydræ | f | 3 | 21 | n | 0 | 22 | 1 | F. mE. unequally B. 3′l. 1′ b. |
| 558 | 25 | 21 (*γ*) Virgin | f | 10 | 43 | f | 0 | 38 | 1 | F. E. mer. 3′l. f. cBſt. |
| 559 | — | 49 (*g*) — | p | 14 | 43 | n | 1 | 33 | 1 | F. S. |
| 560 | — | — — — | p | 13 | 0 | n | 0 | 31 | 1 | pF. pS. iR. |
| 561 | — | — — — | p | 3 | 39 | n | 0 | 24 | 1 | pB. pL. R. vgmbM. |
| 562 | 27 | 16 (*κ*) Crater | f | 4 | 56 | f | 1 | 54 | 2 | F. S. iR. bM. r. |
| 563 | — | 68 (*ι*) Virgin | p | 29 | 28 | f | 0 | 55 | 1 | pB. iF. bM. |
| 564 | 28 | 19 Urſæ | p | 3 | 1 | n | 0 | 23 | 1 | pB. S. R. mbM. |
| 565 | — | 46 Leo. min. | p | 5 | 3 | n | 0 | 28 | 1 | pB. cL. iF. lbM. |
| 566 | — | *1102 (*ε*) Hy | f | 35 | 28 | n | 0 | 53 | 1 | F. pS. E. * See note. |
| 567 | — | — — — | f | 37 | 17 | n | 0 | 51 | 1 | pB. pL. iF. gbM. |
| 568 | | | | | | | | | | |
| 569 | Apr. 17 | 11 (*ι*) Virgin | f | 10 | 14 | n | 0 | 34 | 1 | Four nebulæ. They are ſcattered about. The place is that of the laſt. |
| 570 | | | | | | | | | | |
| 571 | | | | | | | | | | |
| 572 | — | — — — | f | 11 | 34 | f | 0 | 26 | 1 | A nebula. |
| 573 | 23 | — — — | f | 10 | 18 | f | 0 | 26 | 1 | A nebula, cloudy. |
| 574 | 29 | 3 Serpentis | p | 40 | 48 | f | 0 | 20 | 1 | F. S. lE. r. p. 2 veſt. |
| 575 | — | — — | p | 36 | 3 | n | 0 | 33 | 1 | pB. cL. iR. mbM. |
| 576 | — | — — | p | 21 | 26 | f | 0 | 54 | 1 | F. S. lE. like 2 ſtellar, joined cloſely. |
| 577 | 30 | 37 Virginis | p | 11 | 22 | n | 0 | 4 | 1 | F. S. making a triangle with 2 Bſt. |
| 578 | — | — — | p | 2 | 29 | n | 0 | 20 | 1 | F. S. |
| 579 | — | 109 — | p | 26 | 11 | n | 2 | 10 | 1 | pB. cL. E. |
| 580 | — | — — — | p | 16 | 35 | n | 1 | 24 | 1 | Two. The ſ. pB. pL. R. gbM. The n. F. cL. diſt. 2′. The place is of 1. |
| 581 | | | | | | | | | | |
| 582 | — | — — — | p | 8 | 33 | n | 0 | 25 | 1 | F. mE. r. 2′ l. ¼ b. f. ſtóm. 16″ in time. |
| 583 | May 3 | 14 (1ſt A) Ser | f | 17 | 48 | f | 1 | 2 | 2 | pB. S. E. nearly par. bM. |
| 584 | 26 | 5 (*g*) Ophiuc | f | 27 | 48 | n | 1 | 8 | 1 | pB. cL. gbM. er. undoubtedly ſt. |
| 585 | 27 | 3 Serpentis | p | 5 | 43 | f | 1 | 52 | 1 | F. S. iE. r. |
| 586 | 28 | 45 (*ε*) Ophiuc | f | 28 | 13 | n | 0 | 57 | 1 | pB. S. iF. |

587

| H. | 1785 | | Stars. | | M. | S. | D. | M. | | Obs | Description. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 587 | June | 3 | 61 Ophiuchi | f | 0 | 23 | n | 0 | 36 | 1 | F. cL. iF. |
| 588 | Sept. | 4 | 24 (ξ) Ariet | p | 39 | 40 | s | 0 | 17 | 2 | F. S. lE r. bM. |
| 589 | | — | — — — | p | 36 | 21 | n | 0 | 50 | 2 | F. pL. E. b. f. M. 2′ sp. cBst. |
| 590 | | 18 | 2 Piscium | f | 2 | 2 | n | 0 | 48 | 1 | F. S. bM. |
| 591 | | — | 88 (γ) Pegasi | p | 4 | 29 | n | 0 | 38 | 1 | F. pL. iF. unequally B. |
| 592 | | — | 85 Ceti | p | 3 | 19 | n | 0 | 5 | 1 | pB. S. E. bM. |
| 593 | | 20 | 54 Eridani | p | 61 | 14 | n | 0 | 43 | 1 | pB. pS. R. resembling I. 107. but less. |
| 594 | | — | — — | p | 55 | 40 | n | 0 | 10 | 1 | pB. vS. R. bM. |
| 595 | | 23 | 66 Aquarii | p | 41 | 2 | s | 0 | 1 | 2 | F. cL. l and iE. nearly par. lbM. |
| 596 | | 30 | 51 Ceti | f | 10 | 14 | n | 0 | 51 | 1 | F. S. bM. 1′ s Sst. |
| 597 | | — | 32 Eridani | p | 8 | 30 | s | 1 | 10 | 2 | F. S. E. iF. in a row with some st. |
| 598 | Oct. | 13 | 59 (ε) Aqua | f | 13 | 11 | s | 1 | 39 | 1 | pB. pL. iR. vgmbM. |
| 599 | | 17 | 77 Cygni | f | 20 | 15 | s | 0 | 6 | 1 | F. pS. E. er. |
| 600 | | — | 10 Andromæ | f | 2 | 5 | s | 1 | 14 | 2 | pB. mE. np ff. but near. mer. lbM. r. 5′ l. 1′½ b. also ob. 1784. |
| 601 | | — | 26 (β) Persei | p | 15 | 16 | n | 1 | 14 | 1 | F. S. iF. r. |
| 602 | | — | — — — | p | 13 | 38 | n | 0 | 34 | 1 | F. pS. iR. lbM. |
| 603 | | — | — — — | f | 11 | 27 | n | 0 | 35 | 1 | pB. stellar. or pcst. with S. vF. chev. |
| 604 | | 18 | 59 Andromæ | p | 2 | 10 | s | 0 | 17 | 1 | pB. cL. lE. mbM. |
| 605 | | — | — — | p | 0 | 54 | n | 0 | 9 | 1 | pB. S. iF. |
| 606 | | 24 | 6 Lacertæ | p | 17 | 44 | n | 2 | 18 | 3 | F. S. er. or rather a patch of st. |
| 607 | | — | 30 Persei | p | 12 | 50 | s | 1 | 44 | 1 | F. cL. E. |
| 608 | | — | — — | p | 11 | 45 | n | 0 | 19 | 1 | F. cL. er. some st. visible. |
| 609 | | 26 | 65 (ι) Piscium | p | 1 | 55 | s | 0 | 6 | 1 | pB. S. iR. gbM. |
| 610 | | — | 90 (υ) — | f | 24 | 26 | n | 1 | 31 | 1 | F. S. bM. r. |
| 611 | | — | — — — | f | 27 | 38 | n | 0 | 41 | 1 | F. S. lE. |
| 612 | | — | 10 (a) Triang. | p | 28 | 30 | s | 1 | 8 | 1 | pB. pL. lE. nearly par. mbM. |
| 613 | | — | — — — | p | 4 | 46 | s | 0 | 47 | 1 | F. S. lE. par. bM. |
| 614 615 | | — | 34 (δ) Gemin | p | 5 | 37 | s | 0 | 25 | 1 | Two. The f. F. S. R. bM. The n. F. cS. R. bM. |
| 616 | | — | 66 (α) — | f | 9 | 32 | s | 0 | 11 | 1 | F. S. lbM. |
| 617 | Nov. | 13 | 6 (β) Arietis | p | 3 | 55 | n | 0 | 56 | 1 | F. cL. vglbM. |
| 618 | | — | — — — | p | 3 | 23 | n | 1 | 45 | 1 | vS. stellar. |
| 619 | | — | 52 — | p | 5 | 39 | s | 0 | 3 | 1 | pB. cL. pmE. mer. r. 1′ s. st. |
| 620 | Dec. | 11 | 27 (κ) Persei | p | 5 | 48 | n | 1 | 31 | 2 | F. S. iR. bM. L. stellar. |
| 621 | | 13 | 34 Ceti | p | 23 | 45 | s | 0 | 34 | 1 | F. E. np ff. lbM. 1′½ l. |
| 622 | | 20 | 26 — | f | 9 | 8 | s | 0 | 22 | 1 | F. R. bM. er. |
| 623 | | 21 | 2 (ι) Corvi | p | 16 | 4 | s | 0 | 33 | 2 | F. S. E. mer. or few deg. np ff. lb. f. M. |
| 624 | | 29 | 1 Sextantis | f | 8 | 54 | s | 1 | 8 | 1 | F. lE. nearly par. 1′½ l. |
| 625 | | — | 29 (γ) Virgin | p | 17 | 56 | s | 1 | 58 | 2 | pB. mE. 20° sp nf. 2′ l. |
| 626 | | 30 | 77 (σ) Leonis | p | 4 | 44 | s | 1 | 30 | 1 | pB. S. lE. mbM. |
| | 1787 | | | | | | | | | | |
| 627 | Jan. | 11 | 55 (δ) Gemi | f | 54 | 51 | s | 0 | 26 | 3 | F. S. iF. lE. sp nf. |
| 628 | | 14 | 6 Comæ | f | 6 | 36 | n | 0 | 38 | 1 | pB. cL. E. |
| 629 | | — | — — | f | 13 | 46 | s | 0 | 49 | 1 | F. |

630

| H. | 1787 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 630 | Jan. 14 | 6 Comæ | f | 13 | 20 | ſ | 0 | 56 | 1 | cL. |
| 631 | — | — — | f | 16 | 3 | ſ | 1 | 31 | 1 | F. |
| 632 | — | 29 — | p | 8 | 57 | n | 1 | 12 | 1 | F. pL. R. vgbM. |
| 633 | 17 | 16(1ſt p) Perſ | p | 7 | 2 | ſ | 1 | 1 | 1 | F. cL. lbM. 4′ dia. |
| 634 | Feb. 4 | 33 (ν) Canesi | p | 12 | 7 | n | 0 | 34 | 1 | F. S. bM. |
| 635 | 22 | 21 (ϕ) Crater | p | 13 | 5 | n | 1 | 9 | 1 | F. pS. iR. vgbM. |
| 636 | — | 65 Virgin | p | 43 | 8 | ſ | 0 | 49 | 1 | F. vL. bM. |
| 637 | March 11 | 44 (k) — | f | 12 | 41 | ſ | 0 | 36 | 1 | F. cL. iR. lbM. time inaccurate. |
| 638 | 15 | *1139(r) Ce | f | 22 | 49 | ſ | 0 | 12 | 1 | pB. S. lE. ſp nf. * See note. |
| 639 | 17 | 32 Leo. min. | p | 16 | 31 | ſ | 0 | 11 | 1 | pB. cS. r. |
| 640 | — | — — — | p | 16 | 11 | ſ | 0 | 18 | 1 | F. vS. r. with 300 the ſame. |
| 641 | — | 38 — | f | 2 | 41 | ſ | 0 | 36 | 2 | F. vS. |
| 642 | — | 6 Canum | p | 15 | 18 | n | 0 | 30 | 2 | pB. S. E. |
| 643 | — | 10 — | p | 0 | 37 | ſ | 2 | 11 | 1 | F. pL. gbM. r. |
| 644 | — | — — | f | 2 | 55 | ſ | 1 | 1 | 1 | pB. S. R. mbM. among ſcattered ſt. |
| 645 | — | — — | f | 4 | 33 | ſ | 1 | 2 | 1 | pB. S. R. mbM. |
| 646 | — | 17 — | f | 12 | 21 | n | 0 | 12 | 1 | pB. L. iF. uneq. B. 3. or 4′ dia. |
| 647 | — | 12(λ)Coronæ | f | 33 | 4 | n | 1 | 27 | 1 | F. S. iF. |
| 648 | 18 | 53(2d ι) Boot | p | 55 | 31 | n | 1 | 11 | 2 | pB. pL. lbM. |
| 649 | — | — — — | p | 54 | 11 | ſ | 0 | 13 | 2 | F. S. E. nearly mer. r. |
| 650 | — | — — — | p | 16 | 19 | n | 0 | 13 | 3 | pB. E. BNM. and F. br. 2′l. ½ b. |
| 651 | — | — — | p | 5 | 42 | n | 0 | 51 | 2 | pB. pL. iE. er. |
| 652 | — | 30(g) Hercul | p | 0 | 57 | ſ | 0 | 57 | 1 | F. pL. r. |
| 653 | 19 | 70 Virginis | p | 4 | 21 | n | 0 | 11 | 1 | pB. vS. mbM. juſt p. pcſt. |
| 654 | — | 9 Serpentis | f | 7 | 56 | ſ | 0 | 28 | 1 | F. E. np ff. 1′½ l. |
| 655 | — | — — | f | 15 | 44 | n | 0 | 16 | 1 | F. E. mer. 1′½ l. |
| 656 | — | — — | f | 16 | 59 | ſ | 1 | 17 | 1 | pB. E. npff. bM. 1′½ l. |
| 657 | — | 28 (β) — | f | 8 | 2 | ſ | 0 | 52 | 1 | F. iF. bM. 1′½ dia. between 2Bſt. |
| 658 | 20 | 44 Lyncis | p | 47 | 39 | ſ | 0 | 23 | 1 | pF. vS. mbM. |
| 659 | — | 13 Canum | p | 18 | 44 | n | 1 | 47 | 1 | F. S. R. juſt np. V. 42. |
| 660 | April 9 | 8 — | f | 7 | 58 | ſ | 0 | 5 | 1 | pB. pL. R. mbM. |
| 661 | — | — — | f | 9 | 42 | ſ | 0 | 20 | 1 | pB. vS. ſtellar. juſt p. Sſt. |
| 662 | — | — — | f | 15 | 2 | n | 0 | 36 | 1 | F. S. R. bM. |
| 663 | — | 19 — | p | 9 | 58 | n | 0 | 56 | 1 | pB. vS. ſtellar. near and n. Sſt. |
| 664 | — | — — | p | 3 | 47 | n | 3 | 13 | 2 | pB. mE. ſp nf. near. mer. 5′ l. ¾ b. |
| 665 | — | 20 — | f | 2 | 52 | n | 2 | 31 | 1 | pB. cS. E. with 300 ſt. with burrs. |
| 666 | — | — — | f | 5 | 24 | n | 2 | 30 | 1 | pB. S. iR. mbM. |
| 667 | — | — — | f | 7 | 35 | n | 2 | 42 | 1 | pB. vS. lE. bM. |
| 668 | — | — — | f | 27 | 51 | n | 0 | 51 | 1 | F. E. par. miniature of I. 170. |
| 669 | — | — — | f | 33 | 20 | n | 0 | 41 | 1 | pB. pL. vgmbM. |
| 670 | — | — — | f | 35 | 10 | n | 2 | 37 | 1 | pB. pL. |
| 671 | — | — — | f | 37 | 51 | n | 0 | 35 | 1 | pB. pL. E. |
| 672 | — | — — | f | 43 | 59 | n | 0 | 17 | 1 | pF. pS. bM. |
| 673 | — | — — | f | 66 | 36 | n | 1 | 0 | 1 | F. pL. E. vlbM. |
| 674 | — | — — | f | 71 | 16 | n | 0 | 27 | 1 | pB. E. nearly par. 1′½ l. ½ b. |

675

| II. | 1787 | Stars. | | M. | S. | | D.M. | Ob | | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 675 | April 9 | 20 Canum | f | 80 | 7 | n | 0 51 | 1 | | F. vS. |
| 676 | — | — — | f | 98 | 12 | n | 1 42 | 1 | | pB. vS. ſtellar. |
| 677 | — | — — | f | 99 | 9 | n | 1 39 | 1 | | F. pS. lbM. |
| 678 | — | — — | f | 117 | 42 | n | 1 1 | 1 | | F. S. r. in a row with 3 ſt. |
| 679 | 11 | 79 (ζ) Virgin | p | 4 | 17 | f | 1 1 | 2 | Two. The p. F. pS. iF. | |
| 680 | | | | 4 | 7 | | 1 4 | | The f. pB. pL. iF. bM. | |
| 681 | — | 1 Serpentis | p | 19 | 44 | f | 0 7 | 2 | | pB. pL. iF. |
| 682 | — | — — | p | 16 | 35 | f | 0 4 | 2 | | pB. cS. lE. |
| 683 | — | — — | f | 0 | 49 | f | 0 55 | 1 | | pB. pL. R. mbM. ff. cſt. |
| 684 | — | 4 — | p | 6 | 6 | n | 0 7 | 1 | Two. The 2d pB. S. iE. for the 1ſt ſee II. 545. | |
| 685 | 15 | 90 (ρ) Virgin | p | 2 | 37 | f | 0 44 | 2 | | F. pL. iR. f. and par. with 2 Fſt. |
| 686 | — | — — — | p | 0 | 37 | n | 0 4 | 2 | | pB. S mbM. |
| 687 | — | 102 (1ſt υ) — | p | 6 | 18 | f | 0 57 | 2 | | pB. cL. mE. 20° ſp nf. |
| 688 | May 11 | 19 (λ) Bootis | p | 30 | 37 | n | 0 7 | 2 | | F. mE. 15° ſp nf. lbM. 4′ l. ¾ b. |
| 689 | 12 | — — — | p | 47 | 20 | n | 0 46 | 3 | | pB. pL. R. mbM. |
| 690 | — | 22 (τ) Hercu | f | 7 | 2 | n | 2 3 | 2 | | F. pL. iF. gbM. |
| 691 | 15 | 85 (υ) Urſæ | f | 15 | 34 | f | 0 12 | 1 | | pB. pL. E. nearly par. mbM. |
| 692 | — | — — — | f | 19 | 36 | n | 1 20 | 1 | Two. The p. F. pS. R. vgbM. The f. F. vS. ſtellar. ſmbM. diſt. 2′½. | |
| 693 | | | | | | | | | | |
| 694 | — | 24 (g) Bootis | p | 6 | 31 | n | 0 43 | 1 | | pF. pS. lE. mbM. |
| 695 | — | — — — | f | 1 | 7 | f | 0 12 | 1 | | pB. cL. iR. vgmbM. |
| 696 | — | — — — | f | 3 | 40 | n | 0 3 | 1 | | pB. S. E. |
| 697 | 16 | *C Canu. 6m | f | 6 | 23 | f | 0 39 | 1 | | F. E. par. bM. 1′½ l. 1′ b. *See note. |
| 698 | — | — — — | f | 10 | 0 | f | 0 58 | 1 | | F. S. R. vſmbM. |
| 699 | — | — — — | f | 13 | 19 | n | 0 20 | 3 | | F. pL. R. lbM. 1′½ dia. |
| 700 | — | 27 (γ) Bootis | f | 5 | 15 | n | 0 9 | 1 | | pF. S. iE. |
| 701 | — | 25 Herculis | f | 17 | 43 | f | 0 40 | 1 | | pB. pS. E. ſp nf. vgmbM. |
| 702 | Sept. 11 | 68 (2d g) Aqu | f | 4 | 23 | f | 1 1 | 1 | pF. pL. E. np ff. but near. par. mbM. 1′½ l. | |
| 703 | — | *A Ceti 7m | f | 4 | 47 | n | 1 7 | 1 | F. cL. E. * See note. | |
| 704 | 16 | 47 Caſſiop | f | 61 | 37 | n | 3 48 | 2 | | F. pL. mE. np ſf. mbM. |
| 705 | Nov. 3 | 25 Cephei | f | 21 | 6 | f | 1 35 | 1 | | pB. S. iR. er. almoſt equally B. |
| 706 | — | 1 (ε) Caſſiop | f | 6 | 26 | n | 2 5 | 2 | pBM. 2cſt. involved in nebuloſity. 2′ l. 1′½ b. | |
| 707 | 30 | 19 (ξ) — | p | 2 | 50 | f | 2 12 | 1 | | pB. vL. iR. vgmbM. r. 5 or 6 dia. |
| 708 | 1788 Jan. 14 | 37 Lyncis | f | 3 | 50 | f | 1 15 | 1 | | pB. S. ſtellar. |
| 709 | — | 56 Urſæ | p | 6 | 51 | f | 1 57 | 2 | | pB. S. lE. mer. bM. |
| 710 | — | 27 (γ) Bootis | p | 43 | 42 | n | 1 51 | 1 | | F. S. |
| 711 | — | — — — | p | 42 | 47 | n | 1 50 | 1 | | pB. cL. iF. |
| 712 | — | — — — | p | 41 | 48 | n | 1 25 | 1 | | F. S. R. bM. |
| 713 | — | — — — | p | 39 | 13 | n | 2 12 | 2 | | pB. pL. |
| 714 | — | — — — | p | 39 | 5 | n | 2 9 | 2 | Two. Both pB. S. R. 2′ diſt. in the ſame mer. | |
| 715 | | | | | | | | | | |

716

| H. | 1788 | Stars. | | M. | S. | | D. | M. | ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 716 | Jan. 14 | 27 (γ) Bootis | p | 36 | 48 | n | 2 | 19 | 2 | pB. L. iR. FN. mbM. 4 or 5′ dia. |
| 717 | 15 | 15 Leo. min. | f | 0 | 58 | ſ | 1 | 58 | 1 | F. pL. iF. lbM. |
| 718 | — | 45 (ο) Urſæ | p | 2 | 24 | n | 0 | 32 | 2 | pB. S. lE. the np. corner of a S. trapezium. |
| 719 | Feb. 3 | 32 Lyncis | p | 20 | 34 | ſ | 0 | 16 | 1 | F. pL. iR. bM. |
| 720 | — | 34 (μ) Urſæ | p | 2 | 13 | n | 1 | 29 | 1 | F. vS. |
| 721 | — | — — — | p | 1 | 57 | n | 1 | 26 | 1 | F. vS. ſtellar. |
| 722 | — | — — — | p | 1 | 43 | n | 1 | 27 | 1 | F. vS. ſtellar. |
| 723 | — | 13 Canum | p | 73 | 0 | ſ | 0 | 22 | 1 | pB. S. lE. |
| 724 | — | — — | p | 65 | 22 | ſ | 0 | 44 | 1 | F. vS. |
| 725 | — | — — | p | 61 | 59 | ſ | 0 | 19 | 1 | pB. E. ſp nf. but nearer mer. mbM. 2′l |
| 726 | 5 | 80 (π) Gemi | f | 22 | 56 | n | 0 | 38 | 1 | pF. pL. iR. lbM. r. ſ. 2 ſt. par. |
| 727 | — | 59 (2σ) Canc | p | 13 | 13 | n | 1 | 47 | 1 | pF. pL. iR. r. |
| 728 | — | 60 Urſæ | p | 25 | 2 | n | 1 | 32 | 2 | pB. pL. vgmbM. |
| 729 | — | — — | p | 20 | 38 | ſ | 1 | 4 | 2 | F. cL. lE. par. lbM. |
| 730 | — | — — | p | 5 | 27 | n | 0 | 14 | 1 | pB. bM. r. 4′ l. 3′ b. |
| 731 | — | — — | p | 0 | 54 | n | 1 | 5 | 2 | pB. S. E. ſp nf. |
| 732 | — | — — | f | 0 | 47 | ſ | 0 | 19 | 1 | F. S. almoſt. betw. 2ſp. ſt. chev. touches them. |
| 733 | 6 | 59 — | f | 20 | 28 | n | 0 | 21 | 1 | pB. mE. mer. pBSN. &vF. br. 4′ l. 2′ b. |
| 734 | 9 | 20 Lyncis | p | 14 | 20 | n | 0 | 28 | 1 | F. pL. iF. mbM. ff. a triangle of S. ſt. |
| 735 | — | — — | p | 12 | 44 | ſ | 1 | 37 | 1 | F. ſtellar. |
| 736 | — | — — | p | 11 | 9 | ſ | 0 | 3 | 1 | pF. vS. lbM. r. |
| 737 | — | 63 (χ) Urſæ | p | 4 | 55 | ſ | 0 | 4 | 2 | pF. pS. iR. lbM. |
| 738 | — | — — — | f | 2 | 30 | n | 0 | 57 | 1 | pB. pL. R. mbM. |
| 739 | — | — — — | f | 2 | 50 | n | 0 | 56 | 1 | F. vS. |
| 740 | — | — — — | f | 5 | 48 | n | 0 | 56 | 1 | pF. pS. ſtellar. |
| 741 | — | — — — | f | 17 | 7 | n | 0 | 53 | 1 | pF. S. R. gbM. |
| 742 | — | 3 Canum | p | 1 | 50 | ſ | 1 | 35 | 2 | F. S. E. |
| 743 | — | — — | f | 5 | 22 | ſ | 0 | 10 | 1 | F. S. |
| 744 | — | — — | f | 21 | 50 | n | 1 | 27 | 2 | pF. S. er. |
| 745 | April 1 | Neb. II. 728. | p | 35 | 22 | ſ | 0 | 57 | 2 | pF. pS. E. f. &lp. ſt. among ſt. not con. |
| 746 | 8 | 54 Virginis | p | 0 | 24 | ſ | 0 | 43 | 1 | pB. S. pBN. |
| 747 | 10 | 60 Urſæ | f | 31 | 58 | ſ | 0 | 24 | 1 | pB. E. 15 or 20° np ff. 3′ l. |
| 748 | — | — — | f | 38 | 3 | n | 0 | 16 | 1 | pB. pL. E. ſp. and in a line with 2ſt. |
| 749 | — | — — | f | 47 | 57 | ſ | 1 | 10 | 2 | pB. pL. iF. |
| 750 | 27 | 19 (λ) Bootis | p | 109 | 46 | ſ | 1 | 1 | 1 | pF. pL. E. ſp nf. |
| 751 | — | — — | f | 16 | 12 | n | 0 | 25 | 2 | Two. The p. cF. cS. The f. pF. pL. |
| 752 | — | 37 (ξ) — | f | 16 | 20 | n | 0 | 24 | 2 | Both lE. np ff. but nearer par. |
| 753 | 28 | 27 (β) Hercul | f | 2 | 50 | ſ | 1 | 42 | 1 | pF. pS. vlE. mbM. |
| 754 | 29 | 27 (γ) Bootis | p | 11 | 15 | n | 1 | 27 | 1 | pB. pL. R. FN. |
| 755 | May 1 | 23 (θ) — | f | 44 | 59 | n | 0 | 31 | 1 | pB. pL. lE. |
| 756 | 5 | Neb. II. 757. | p | 11 | 47 | ſ | 3 | 7 | 2 | pB. pL. iF. r. |
| 757 | — | 12 (ι) Draco | p | 16 | 38 | ſ | 1 | 56 | 3 | pB. S. iR. or lE. mbM. |
| 758 | — | Neb. II. 757. | f | 5 | 28 | ſ | 1 | 31 | 1 | pF. pS. iR. |

| II. | 1788 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 759 | May 5 | Neb. II. 757. | f | 6 | 6 | ſ | 0 | 42 | 1 | pB. FNM. 8 or 10′ l. 2′ b. |
| 760 | | — — — — | f | 6 | 29 | ſ | 1 | 37 | 1 | pF. pS. R. |
| 761 | | — — — — | f | 24 | 8 | ſ | 0 | 33 | 1 | pF. pS. iF. |
| 762 | | — — — — | f | 24 | 37 | ſ | 0 | 25 | 1 | pF. pL. E. |
| 763 | 25 | 12 (ι) Draco | p | 13 | 7 | n | 0 | 54 | 2 | pB. mE. nearly mer. 2′ l. ½′ b. |
| 764 | | — — — — | f | 13 | 58 | n | 0 | 20 | 1 | pB. S. iR. one p. ſuſpected vF. lE. |
| 765 | | — — — — | f | 14 | 36 | ſ | 0 | 58 | 1 | pF. cS. |
| 766 | | — — — — | f | 15 | 0 | n | 0 | 18 | 1 | pB. cL. iE. r. |
| 767 | June 6 | 31 (1ſt ♈) — | p | 31 | 23 | n | 0 | 15 | 1 | pB. pL. R. vgmbM. |
| 768 | Nov. 4 | 14 Camelop | p | 42 | 52 | n | 1 | 57 | 1 | pB. S. lE. BN. juſt ſ. pB. ſt. |

## Third claſs. Very faint nebulæ.

| III. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 377, 378 | April 26 | 92 Leonis | f | 3 | 6 | ſ | 1 | 24 | 2 | Two. The n. F. S. lbM. The ſ. vF. vS. diſt. 5′ ſp. the place of n. |
| 379 | — | 1 Comæ | p | 10 | 26 | ſ | 0 | 6 | 3 | vF. vS. lE. er. or S. patch of ſt. |
| 380 | — | — — | p | 8 | 56 | ſ | 1 | 7 | 2 | F. S. |
| 381 | — | — — | p | 7 | 56 | ſ | 1 | 12 | 1 | vF. R. |
| 382, 383, 384 | — | 2 — | f | 1 | 58 | ſ | 0 | 49 | 2 | Three. The place is of the laſt or moſt n. which is vF. S. The other two are ſp. eF. vS. |
| 385 | 27 | 93 Leonis | p | 2 | 54 | ſ | 0 | 35 | 1 | vF. vS. r. |
| 386 | — | — — | p | 3 | 10 | ſ | 0 | 27 | 1 | vF. vS. r. |
| 387 | — | — — | p | 2 | 10 | ſ | 0 | 27 | 1 | vF. vS. r. |
| 388 | — | — — | p | 1 | 48 | n | 0 | 11 | 2 | vF. pL. iR. lbM. r. 7′ nf. cBſt. |
| 389 | — | — — | f | 4 | 49 | n | 0 | 25 | 1 | vF. vS. |
| 390 | — | 5 Comæ | p | 8 | 56 | ſ | 1 | 47 | 1 | Suſpected. |
| 391, 392, 393, 394, 395, 396 | — | — — | p | 7 | 54 | ſ | 0 | 15 | 2 | Six nebulæ. The places belong to the three firſt which are vF. vS. The other three are 10 or 12′ more ſouth, but there was not time to take their places: more ſuſpected. |
| 397 | — | — — | f | 3 | 36 | n | 0 | 5 | 2 | vF. vL. iR. bM. 6′ l. 5′ b. |
| 398 | — | 26 — | f | 8 | 12 | ſ | 1 | 33 | 1 | vF. vS. r. |
| 399 | 28 | 61 Urſæ | f | 31 | 26 | n | 1 | 57 | 2 | vF. pL. lE. r. |
| 400 | May 1 | — — | f | 25 | 34 | n | 2 | 38 | 4 | vF. vS. ſtellar. 2′½ n. Sſt. |
| 401 | — | 14 Canum | f | 2 | 36 | ſ | 0 | 36 | 1 | vF. ſtellar. with 300 the ſame. |
| 402, 403 | — | — — | f | 19 | 23 | n | 0 | 35 | 1 | Two. Both vF. cS. The place is that of the p. The 2d, 3′ nf. |
| 404, 405 | — | — — | f | 20 | 44 | n | 0 | 7 | 1 | Two. Both vF. pS. The place is of the p. The 2d, 5 or 6′ nf. |
| 406 | — | — — | f | 25 | 14 | ſ | 0 | 59 | 1 | vF. vS. lE. |

| III. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 407 | May 1 | 49 (J) Bootis | p | 102 | 40 | n | 1 | 37 | 2 | Two. Both vF. vS. A star between them about half way. |
| 408 | | | | 102 | 22 | | 1 | 39 | | |
| 409 | | 14 Canum | f | 30 | 38 | f | 0 | 17 | 1 | vF. pL. R. lbM. |
| 410 | | | f | 35 | 6 | n | 1 | 1 | 1 | vF. S. lE. er. |
| 411 | | | f | 54 | 30 | f | 1 | 8 | 1 | eF. vS. |
| 412 | | | f | 54 | 45 | n | 0 | 25 | 1 | vF. vS. |
| 413 | | | f | 58 | 30 | f | 0 | 53 | 1 | vF. |
| 414 | | 51 (μ) Bootis | p | 70 | 6 | f | 0 | 55 | 1 | vF. mE. |
| 415 | | | p | 65 | 4 | f | 1 | 57 | 1 | eF. pL. |
| 416 | | | p | 64 | 2 | f | 1 | 57 | 1 | Two. Both vF. S. dist. 6 or 7'. The place is that of the ff. |
| 417 | | | | | | | | | | |
| 418 | | | p | 62 | 52 | f | 0 | 6 | 1 | eF. stellar. |
| 419 | | | p | 61 | 4 | f | 0 | 42 | 1 | vF. vS. E. er. |
| 420 | | | p | 54 | 54 | f | 0 | 50 | 1 | vF. S. |
| 421 | | | p | 49 | 26 | f | 0 | 40 | 1 | vF. vS. |
| 422 | 2 | 49 (J) | p | 86 | 2 | n | 0 | 24 | 1 | Two. Both eF. stellar. dist. 4 or 5'. nearly mer. The n. faintest. |
| 423 | | | | | | | | | | |
| 424 | 3 | | p | 147 | 32 | n | 0 | 11 | 1 | vF. stellar. or little larger. |
| 425 | | | p | 101 | 48 | n | 1 | 39 | 1 | vF. vS. in the field with III. 407. 408. |
| 426 | Aug. 30 | 17 (ι) Piscium | p | 8 | 48 | f | 1 | 42 | 1 | eF. pL. iR. |
| 427 | | 19 | f | 0 | 14 | n | 0 | 19 | 1 | vF. S. lE. nearly mer. |
| 428 | Sept. 10 | 30 | f | 14 | 30 | f | 0 | 19 | 2 | vF. S. iF. lbM. |
| 429 | | 41 Ceti | p | 26 | 42 | n | 0 | 35 | 1 | vF. pS. E. |
| 430 | | | p | 26 | 54 | n | 0 | 44 | 1 | vF. vS. |
| 431 | | Neb. I. 100. | f | 0 | 22 | n | 0 | 0 | 1 | The 2d of two. eF. S. 5 or 6' dist. from I. 100. |
| 432 | | 41 Ceti | f | 15 | 36 | n | 0 | 22 | 1 | eF. |
| 433 | | 67 | p | 15 | 39 | n | 0 | 59 | 1 | vF. vS. |
| 434 | | | f | 18 | 40 | f | 0 | 42 | 1 | vF. cL. iF. lbM. 4 or 5' l. 2 or 3' b. |
| 435 | 26 | 59 (p) Pegasi | f | 8 | 42 | f | 0 | 20 | 1 | vF. vS. |
| 436 | | 32 (2d c) Pisc | f | 1 | 20 | f | 1 | 1 | 1 | vF. pL. lbM. |
| 437 | 27 | 26 | p | 7 | 39 | f | 0 | 13 | 1 | eF. vS. er. confirmed by 240. |
| 438 | 28 | 93 (2 τ) Aquæ | f | 9 | 22 | f | 0 | 15 | 1 | eF. S. stellar. p. 1'½. pBf. |
| 439 | Oct. 1 | 20 Ceti | p | 0 | 42 | f | 1 | 3 | 2 | vF. S. iE. |
| 440 | | 38 | f | 1 | 5 | n | 0 | 8 | 1 | vF. vL. requires great attention. |
| 441 | | 43 | f | 5 | 8 | f | 1 | 29 | 1 | vF. vS. iE. |
| 442 | | | f | 5 | 23 | f | 1 | 26 | 1 | vF. vS. iE. |
| 443 | 5 | 17 Eridani | p | 17 | 51 | f | 0 | 13 | 1 | vF. vS. confirmed by 240. |
| 444 | | | p | 9 | 23 | n | 0 | 25 | 1 | eF. vS. |
| 445 | | | p | 5 | 37 | f | 0 | 41 | 1 | vF. pS. E. |
| 446 | | | p | 3 | 4 | f | 0 | 3 | 1 | vF. S. between some Sst. |
| 447 | | 20 (τ) Orionis | f | 10 | 23 | n | 1 | 32 | 2 | vF. cL. iR. near a hook of vSst. |
| 448 | | | f | 34 | 45 | f | 0 | 26 | 3 | vF. S. R. r. lbM. |
| 449 | 6 | 1 (1 st τ) Eridani | f | 4 | 8 | n | 1 | 34 | 1 | vF. pL. broadly E. lbM. |
| 450 | | | f | 6 | 30 | n | 1 | 56 | 2 | vF. S. lE. |

| III. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | | Description. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 451 | Oct. 6 | 20 Eridani | f | 2 | 30 | f | 0 | 59 | 1 | vF. S. R. | |
| 452 | 8 | 52 (π) Aqua | p | 30 | 46 | n | 1 | 39 | 1 | vF. pL. R. r. | |
| 453 | — | 10 Orionis | f | 5 | 7 | f | 0 | 4 | 1 | vF. vS. confirmed 240. | |
| 454 | 9 | 60 Ceti | p | 27 | 18 | n | 0 | 27 | 1 | eF. pL. 240. left doubtful. | |
| 455 | — | 82 (δ) —— | f | 4 | 11 | n | 1 | 2 | 2 | vF. vL. lbM. er. 6 or 7′ dia. | |
| 456 | 25 | 28(ω)Piſcium | f | 13 | 6 | f | 0 | 28 | 1 | vF. pS. iF. | |
| 457 | — | 78 (ι) Ceti | p | 20 | 29 | n | 0 | 20 | 1 | vF. cL. vlbM. m. p. Bſt. and joining. | |
| 458 | 26 | 49 Aquarii | p | 2 | 52 | n | 0 | 6 | 1 | vF. S. er. time inaccurate. | |
| 459 | — | 56(1ſtυ) Ceti | p | 7 | 44 | f | 1 | 17 | 1 | vF. vS. er. | |
| 460 | — | —— —— —— | p | 2 | 55 | f | 1 | 16 | 1 | vF. vS. | |
| 461 | 27 | 18(ι) Piſ. Au. | f | 90 | 20 | n | 1 | 56 | 1 | vF. cL. lE. glbM. 4 or 5′ l. | |
| 462 | Nov. 7 | 82 (δ) Ceti | f | 8 | 1 | f | 0 | 36 | 1 | vF. S. | |
| 463 | 22 | 25 —— | p | 12 | 56 | f | 0 | 23 | 2 | vF. pL. iR. r. | |
| 464 | — | 67 —— | p | 20 | 11 | n | 0 | 59 | 1 | eF. S. found in gaging. | |
| 465 | 23 | 46 (ξ) Pegaſi | f | 11 | 21 | n | 0 | 54 | 1 | eF. S. iF. 240 the ſame. | |
| 466 | — | 82 —— | f | 5 | 54 | f | 0 | 15 | 1 | vF. S. R. lbM. | |
| 467 | 27 | 18 Ceti | p | 11 | 15 | n | 0 | 12 | 1 | eF. vS. 240 left ſome doubt. | |
| 468 | — | 72 (ζ) —— | p | 27 | 13 | n | 0 | 43 | 1 | vF. E. nearly mer. lbM. 1′½ l. 1′b. | |
| 469 | — | 83 (ι) —— | f | 19 | 27 | f | 0 | 30 | 1 | vF. ſtellar. 240 left ſome doubt. | |
| 470 | 28 | 91 Aquarii | p | 1 | 53 | f | 0 | 7 | 1 | eF. vS. 240 left doubtful. | |
| 471 | — | 53 (χ) Ceti | p | 13 | 54 | n | 0 | 40 | 1 | A few Sſt. mixed with nebulosity. | |
| 472 | — | 55(1ſtζ)—— | f | 41 | 48 | f | 0 | 18 | 1 | vF. pL. vlbM. near ſcattered ſt. | |
| 473 | 29 | 87 (ω) Pegaſi | p | 44 | 53 | f | 1 | 26 | 1 | eF. cL. ſome doubt. p. a row of ſt. | |
| 474 | — | 23(2dϑ) Arie | f | 7 | 29 | n | 0 | 50 | 1 | eF. vS. iR. confir. 240. | |
| 475 | — | 34 (μ) —— | p | 1 | 44 | f | 0 | 44 | 1 | vF. S. confir. 240. | |
| 476 | Dec. 5 | 34 (ζ) Andro | p | 11 | 14 | f | 0 | 23 | 1 | vF. vS. ſtellar. ſp. pBſt. | |
| 477 | — | 36 —— | p | 2 | 25 | n | 0 | 44 | 1 | vF. S. R. juſt p. vFſt. | |
| 478 | 7 | 20 Leo. min. | f | 1 | 20 | n | 0 | 47 | 1 | eF. S. left doubtful. | |
| 479 | 26 | 2(ι)Can. min | f | 26 | 18 | n | 0 | 25 | 1 | ſuſpected. eF. vS. lE. | |
| 480 | 28 | 9 (ι) Virgin | f | 12 | 46 | f | 2 | 5 | 1 | vF. L. ſeen by looking at II. 137. | |
| 481 | — | 31(1ſtd)—— | p | 17 | 49 | n | 1 | 44 | 1 | vF. | |
| 482 | — | —— —— —— | p | 15 | 22 | n | 1 | 39 | 1 | eF. | |
| 483 | — | —— —— —— | p | 12 | 49 | n | 1 | 24 | 1 | vF. | |
| 484 | — | —— —— —— | p | 11 | 8 | n | 1 | 34 | 1 | vF. | |
| 485 | 30 | 46 Ceti | p | 40 | 9 | f | 1 | 4 | 2 | vF. S. iF. r. | |
| 486 | — | 76 (σ) —— | p | 12 | 32 | f | 0 | 52 | 1 | vF. vS. iF. better with 240. | |
| 487 | — | 20 Eridani | p | 3 | 52 | n | 2 | 14 | 1 | vF. S. E. | |
| 488 | 31 | 9 Hydræ | f | 38 | 13 | f | 0 | 26 | 1 | vF. cL. gvlbM. 3′ l. 2′ b. p. pBſt. | |
| 489 | — | 53 Virginis | p | 18 | 36 | f | 0 | 47 | 1 | vF. S. lbM. | |
| | 1786 | | | | | | | | | | |
| 490 | Jan. 1 | 45 Eridani | p | 11 | 41 | f | 0 | 42 | 1 | vF. vS. lE. better with 240. | |
| 491 | — | 13 (ω) Virgin | p | 16 | 10 | n | 0 | 35 | 2 | vF. S. R. bM. | |
| 492 | — | 5 (ω) —— | f | 7 | 0 | f | 0 | 15 | 2 | vF. cL. mE. r. | |
| 493 | — | 49 (γ) —— | p | 6 | 35 | n | 1 | 12 | 2 | eF. S. iF. | |
| 494 | — | —— —— —— | f | 1 | 24 | n | 0 | 48 | 2 | vF. pS. E. | |

| III. | 1786 | | Stars. | | M. | S. | | D. | M. | Obs | Description. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 495 | Jan. | 2 | 61 Ursæ | f | 58 | 0 | f | 0 | 46 | 1 | eF. S. iF. r. |
| 496 | | | —— | f | 70 | 52 | f | 0 | 3 | 1 | eF. vS. pmE. |
| 497 | | 27 | 36 Sextantis | f | 6 | 47 | n | 1 | 20 | 2 | cF. S. R. vlbM. |
| 498 | | | —58 (*d*) Leonis | f | 0 | 43 | n | 0 | 1 | 1 | vF. mE. |
| 499 | | 30 | 39 (A) Erida | p | 6 | 26 | n | 1 | 25 | 1 | vF. S. E. er. |
| 500 | | | —69 (λ) —— | p | 3 | 50 | f | 0 | 24 | 1 | cF. S. iF. bM. |
| 501 | Feb. | 1 | 57 (μ) —— | f | 4 | 13 | n | 0 | 30 | 1 | vF. vS. |
| 502 | | | —— —— —— | f | 6 | 2 | n | 0 | 39 | 1 | vF. S. |
| 503 | | | —— —— —— | f | 14 | 49 | f | 0 | 1 | 1 | vF. pL. sp. 2pBst. equil. triang. |
| 504 | | 2 | 60 (σ) Virg | p | 38 | 27 | n | 0 | 34 | 2 | vF. pS. |
| 505 | | | —64 —— | f | 16 | 1 | f | 0 | 39 | 2 | vF. vS. R. |
| 506 | | | —— —— —— | f | 32 | 47 | n | 0 | 7 | 1 | vF. E. 2′ l. |
| 507 | | 4 | 82 —— | p | 9 | 23 | f | 0 | 4 | 1 | vF. vS. er. 240 rather confir. |
| 508 | | | —19 Libræ | p | 18 | 52 | f | 0 | 27 | 1 | vF. cL. iE. nearly mer. |
| 509 | | 22 | 5 (β) Virgin | f | 49 | 54 | f | 0 | 35 | 1 | vF. vS. |
| 510 | | 24 | 55 Orionis | f | 1 | 13 | n | 0 | 7 | 1 | cF. E. er. probably a patch of st. |
| 511 | | | —110 Virginis | f | 3 | 5 | f | 0 | 25 | 1 | vF. R. precedes l. 128. 7′ ½ and is 5′ n |
| 512 | March | 3 | 17 (β) Cancri | p | 14 | 9 | n | 0 | 9 | 1 | vF. S. R. mbM. 240 ditto. |
| 513 | | | — 6 (*b*) Leonis | f | 2 | 1 | n | 0 | 25 | 1 | eF. vS. stellar. 240 verif. |
| 514 | | | —26 (χ) Virgin | f | 10 | 4 | f | 1 | 8 | 2 | cF. S. mE. |
| 515 | | | —— —— —— | f | 12 | 19 | f | 0 | 26 | 1 | vF. S. E. |
| 516 | | | —— —— —— | f | 14 | 18 | f | 0 | 41 | 1 | vF. S. |
| 517 | | | —— —— —— | f | 14 | 43 | f | 0 | 48 | 1 | vF. S. |
| 518 | | 19 | 41 (λ) Hydræ | p | 10 | 28 | f | 0 | 5 | 1 | vF. S. R. in the field with λ. |
| 519 | | 24 | 1 Sextantis | f | 1 | 47 | n | 0 | 7 | 1 | vF. pL. vgvlbM. betw. 2 groups of st. np. ff. |
| 520 | | 25 | 27 Hydræ | f | 3 | 9 | f | 0 | 51 | 1 | vF. S. E. |
| 521 | | | —— —— —— | f | 22 | 39 | f | 0 | 45 | 1 | cF. pS. lE. |
| 522 | | | —14 (ι) Crater | p | 34 | 1 | f | 2 | 2 | 2 | cF. pL. iR. lb. near M. |
| 523 | | | —21 (η) Virgin | f | 13 | 23 | f | 0 | 38 | 1 | vF. E. sp nf. 4′ l. 3′ b. |
| 524 | | | —— —— —— | f | 15 | 14 | f | 1 | 59 | 2 | cF. mE. r. 4′ l. 2′ b. |
| 525 | | | —49 (*g*) —— | p | 14 | 19 | n | 1 | 14 | 1 | vF. vS. |
| 526 | | | —— —— —— | p | 13 | 15 | n | 0 | 8 | 1 | eF. eS. some little doubt. |
| 527 | | 27 | 8 Sextantis | p | 10 | 33 | f | 0 | 31 | 3 | vF. S. iR. vgbM. |
| 528 | | | —— —— —— | p | 9 | 10 | f | 1 | 32 | 1 | vF. S. E. nearly mer. |
| 529 | | | —16 (ε) Crater | p | 13 | 0 | f | 1 | 46 | 1 | eF. S. |
| 530 | | | —— —— —— | p | 3 | 32 | f | 1 | 30 | 1 | vF. stellar. |
| 531 | | | —— —— —— | p | 2 | 47 | f | 1 | 32 | 1 | cF. stellar, vlbM. |
| 532 | | | —— —— —— | f | 1 | 7 | f | 0 | 51 | 1 | vF. lE. vlb. about M. |
| 533 | | | —24 (ι) —— | f | 28 | 31 | f | 0 | 59 | 1 | vF. S. iF. time a little inacc. |
| 534 | | | —— —— —— | f | 33 | 51 | f | 0 | 48 | 1 | vF. pL. of uneq. light. |
| 535 | | | —— —— —— | f | 40 | 50 | n | 0 | 58 | 2 | vF. pS. iF. |
| 536 | | | —68 (ι) Virgin | p | 36 | 17 | f | 0 | 33 | 1 | cF. stellar. |
| 537 | | | —— —— —— | p | 34 | 23 | n | 0 | 39 | 1 | vF. vS. iF. |
| 538 | | | —— —— —— | p | 31 | 24 | n | 0 | 8 | 2 | eF. S. er. |

| III. | 1786 | Stars. | | M. | S. | | D.M. | | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 539 | Mar. 27 | 68 (ι) Virgin | p | 5 | 57 | ſ | 1 | 21 | 1 | vF. vS. |
| 540 | 28 | 19 Urſæ | p | 15 | 27 | n | 1 | 3 | 2 | vF. S. E. 20° np ff. contains 2vFſt. |
| 541 | — | 8 Leo. min. | f | 9 | 41 | n | 0 | 50 | 3 | cF. S. iR. gbM. r. 1′½ dia. |
| 542 | — | 21 —— | p | 7 | 55 | n | 0 | 8 | 3 | cF. vL. iF. 5′ l. 4′ b. ſp. a double ſt. |
| 543 | April 17 | 11 (ι) Virgin | f | 37 | 39 | ſ | 1 | 31 | 1 | eF. pL. |
| 544 | — | —— —— | f | 43 | 12 | ſ | 1 | 23 | 1 | vF. vS. |
| 545 | — | —— —— | f | 62 | 44 | ſ | 1 | 9 | 1 | eF. cS. er. |
| 546 | 29 | 64 —— | f | 36 | 17 | n | 1 | 4 | 1 | Two. Both vF. vS. r. the place betw. them. ſp nf. but near.mer. |
| 547 | | | | | | | | | | |
| 548 | 30 | 43 (ϑ) —— | p | 0 | 31 | ſ | 0 | 30 | 1 | vF. cS. with 240 lE. near vSſt. |
| 549 | — | 84 (ο) —— | f | 9 | 1 | ſ | 1 | 13 | 1 | eF. vS. ſtellar. confir. 240. |
| 550 | — | 109 —— | p | 5 | 32 | n | 1 | 35 | 1 | vF. S. p. and in a line with 2Bſt. |
| 551 | May 1 | 31 Bootis | p | 23 | 9 | ſ | 0 | 42 | 1 | Two. Both eF. vS. The place is that of the f. diſt. 3 or 4′ |
| 552 | | | | | | | | | | |
| 553 | 3 | 50 (σ) Serpen | p | 12 | 7 | ſ | 0 | 15 | 1 | cF. iF, r. 5′ l. 3′ b. |
| 554 | 27 | 3 —— | p | 21 | 20 | ſ | 1 | 19 | 1 | vF. S. E. np ff. but nearly mer. |
| 555 | June 22 | 101 Hercul | p | 2 | 55 | ſ | 1 | 28 | 1 | cF. S. lE. iF. r. |
| 556 | Sept. 4 | 71 (ι) Piſcium | f | 22 | 10 | n | 1 | 24 | 1 | vF. mE. 75° ſp nf. 1′½ l. |
| 557 | 18 | 85 Ceti | p | 6 | 18 | n | 0 | 52 | 1 | vF. vS. lE. r. 240 the ſame. |
| 558 | 20 | 97 Aquarii | p | 14 | 9 | ſ | 0 | 33 | 1 | eF. cL. iR. 5 or 6′ dia. |
| 559 | — | 54 Eridani | p | 65 | 18 | ſ | 0 | 59 | 1 | 3vSſt. in a line with vF. nebuloſity. |
| 560 | 21 | 45 Androm | f | 16 | 14 | ſ | 0 | 32 | 1 | vF. S. E. among ſt. |
| 561 | — | 58 —— | p | 17 | 32 | ſ | 1 | 34 | 1 | vF. ſtellar. |
| 562 | | | | | | | | | | |
| 563 | | —— —— | p | 15 | 22 | ſ | 1 | 48 | 1 | Four. ſtellar. unequal. Three in a row, and the fourth making a a rectangle with them. That at the angle is much larger. |
| 564 | | | | | | | | | | |
| 565 | | | | | | | | | | |
| 566 | — | —— —— | p | 5 | 4 | n | 0 | 14 | 2 | vF. pL. iR. |
| 567 | — | —— —— | f | 2 | 29 | ſ | 0 | 12 | 1 | vF. S. lE. |
| 568 | 30 | 17 Eridani | p | 8 | 17 | n | 2 | 17 | 1 | eF. S. iF. among 3 or 4 ſt. |
| 569 | — | —— —— | f | 9 | 13 | n | 0 | 27 | 1 | eF. lE. er. |
| 570 | Oct. 17 | 26 (β) Perſei | p | 43 | 39 | n | 0 | 51 | 1 | eF. vS. lE. |
| 571 | — | —— —— | p | 42 | 9 | n | 0 | 44 | 1 | eF. ſtellar. not verified. |
| 572 | — | —— —— | p | 32 | 26 | ſ | 0 | 11 | 1 | Two. Both vF. vS. er. diſt. 4′. the place between them. |
| 573 | | | | | | | | | | |
| 574 | — | —— —— | f | 13 | 6 | n | 0 | 27 | 1 | Two. Both vF. ſtellar. vlbM. but the ſ. is the brighteſt and largeſt. |
| 575 | | | | | | | | | | |
| 576 | 18 | 12 Androm | p | 24 | 27 | ſ | 1 | 47 | 1 | vF. S. iR. ſtellar. |
| 577 | — | 53 (γ) —— | p | 18 | 55 | ſ | 0 | 8 | 1 | vF. pL. lE. lbM. |
| 578 | — | 28 (ω) Perſei | p | 2 | 50 | f | 1 | 16 | 1 | vF. vS. |
| 579 | 24 | 17 (ι) Andro | p | 3 | 21 | n | 1 | 3 | 1 | vF. vS. juſt f. pBſt. |
| 580 | — | 30 Perſei | p | 20 | 43 | ſ | 1 | 3 | 1 | ſuſpected. r. ſome ſt. viſible. |
| 581 | 25 | 40 Arietis | p | 8 | 24 | ſ | 0 | 18 | 1 | vF. E. iF. time inaccurate. |
| 582 | — | —— —— | p | 1 | 17 | ſ | 2 | 7 | 1 | vF. S. iF. |
| 583 | 26 | 10 (α) Triang | p | 18 | 21 | ſ | 0 | 29 | 1 | vF. vS. E. or 3Fſt. with vF. Nebul. |

584

| III. | 1786 | Stars. | | M. | S. | | D. | M. | Obs | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 584 | Oct. 26 | 35 Arietis | p | 0 | 41 | n | 0 | 50 | 1 | vF. S. bM. |
| 585 | Nov. 26 | 48 (ν) Eridani | p | 3 | 33 | ſ | 1 | 2 | 1 | ſuſpected; hazy weather. |
| 586 | — | — — — | p | 3 | 6 | ſ | 0 | 56 | 2 | { eF. S. E. nearly par. another ſuſpec. 3′ ff. ſtellar. |
| 587 | 28 | 42 (ξ) — | f | 2 | 34 | n | 0 | 9 | 1 | vF. S. bM. betw. 2 ſt. |
| 588 | — | — — — | f | 7 | 35 | ſ | 1 | 57 | 1 | vF. S. |
| 589 | — | — — — | f | 10 | 16 | ſ | 1 | 22 | 1 | vF. cL. iE. nearly par. bM. |
| 590 | Dec. 14 | 8 Leporis | f | 9 | 18 | ſ | 0 | 6 | 1 | eF. ſtellar. a little doubtful. |
| 591 | 15 | 13 (ζ) Eridani | p | 4. | 35 | ſ | 0 | 6 | 1 | eF. ſtellar. about 1′ nf. II. 286. |
| 592 | 20 | Neb. II. 447. | p | 0 | 6 | f | 0 | 2 | 1 | { Two. The p. vF. vS. The next |
| 593 | | | | 0 | 0 | | 0 | 5 | | { eF. eS. and left doubtful. |
| 594 | — | 26 Ceti | f | 18 | 21 | ſ | 0 | 23 | 1 | vF. mE. bM. 3′½ l. 1′½ b. |
| 595 | 21 | 29 — | p | 28 | 42 | n | 1 | 17 | 1 | vF. S. ſome ſt. in it. |
| 596 | — | 44 Hydræ | p | 34 | 21 | n | 0 | 50 | 2 | vF. S. lbM. ff. a trapezium of S. ſt. |
| 597 | 24 | — — | p | 59 | 13 | n | 2 | 44 | 1 | vF. S. R. vglbM. |
| 598 | 30 | 59 (c) Leonis | f | 2 | 40 | ſ | 1 | 19 | 1 | eF. S. iE. not verified. |
| 1787 | | | | | | | | | | |
| 599 | Jan. 11 | 55 (δ) Gemini | f | 68 | 4 | ſ | 0 | 12 | 1 | eF. pL. r. |
| 600 | 14 | 30 (ϰ) Leonis | p | 11 | 47 | ſ | 0 | 20 | 1 | vF. S. iR. |
| 601 | — | — — — | p | 11 | 4 | n | 0 | 3 | 1 | vF. cS. lE. er. |
| 602 | — | 29 Comæ | p | 12 | 7 | n | 0 | 6 | 1 | vF. cL. vgbM. f. cBſt. |
| 603 | — | — — | p | 6 | 16 | n | 0 | 11 | 1 | vF. E. np ff. 2′½ l. |
| 604 | 17 | 58 Androm | f | 2 | 45 | ſ | 0 | 21 | 1 | vF. ſtellar. confir. 240. |
| 605 | Feb. 10 | 9 (1ſt μ) Canc | p | 3 | 15 | n | 0 | 46 | 1 | vF. S. iF. |
| 606 | 13 | 10 (2d μ) — | f | 11 | 31 | ſ | 1 | 1 | 2 | vF. S. ſtellar. |
| 607 | — | 33 (ϰ) — | p | 12 | 33 | n | 0 | 38 | 1 | vF. vS. |
| 608 | 22 | 69 (γ) — | f | 2 | 5 | n | 0 | 33 | 1 | eF. S. R. vlbM. |
| 609 | — | 21 (ϑ) Crater | f | 2 | 28 | n | 0 | 28 | 1 | vF. vS. R. with 240 gbM. |
| 610 | — | 65 Virginis | p | 33 | 51 | f | 0 | 12 | 1 | cF. pL. E. |
| 611 | — | — — | p | 32 | 29 | n | 0 | 50 | 1 | vF. S. no time to verify. |
| 612 | March 11 | 87 (ε) Leonis | f | 23 | 23 | ſ | 0 | 57 | 1 | vF. cS. E. |
| 613 | — | 44 (ε) Virgin | p | 1 | 42 | n | 0 | 8 | 1 | vF. E. er. |
| 614 | — | — — — | f | 0 | 57 | ſ | 0 | 49 | 1 | cF. S. iR. |
| 615 | 17 | 38 Leo. min. | p | 1 | 27 | ſ | 0 | 27 | 2 | cF. S. er. |
| 616 | — | 0 Canum | p | 34 | 40 | ſ | 1 | 1 | 2 | vF. cL. iF. 4′ dia. 5′ f. ſt. 6 m. |
| 617 | — | — — | p | 27 | 3 | ſ | 1 | 13 | 2 | eF. pL. iR. 1′ dia. or more. |
| 618 | — | 12 — | p | 3 | 8 | ſ | 1 | 31 | 1 | eF. vS. |
| 619 | — | 17 — | f | 11 | 29 | n | 0 | 2 | 1 | vF. S. E. nearly mer. |
| 620 | — | — — | f | 26 | 36 | ſ | 0 | 14 | 1 | cF. E. nearly par. r. ½′ l. |
| 621 | — | — — | f | 38 | 29 | ſ | 0 | 46 | 1 | vF. S. iR. conf. 300. |
| 622 | — | 12 (λ) Coronæ | f | 7 | 17 | ſ | 0 | 37 | 1 | vF. S. R. diſcov. in gaging. |
| 623 | — | — — — | f | 24 | 7 | ſ | 0 | 19 | 1 | vF. vS. n. 2 ſt. 300 confir. |
| 624 | — | — — — | f | 27 | 24 | ſ | 0 | 9 | 1 | vF. S. bM. diſcov. with 300 |
| 625 | 18 | 10 (n) Urſæ | p | 2 | 41 | ſ | 2 | 27 | 1 | vF. vS. 300. |
| 626 | — | — — — | f | 7 | 14 | ſ | 0 | 4 | 2 | vF. S. iF. lbM. r. |

627

| III. | 1787 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 627 | March 18 | 43 Lyncis | p | 17 | 50 | f | 1 | 2 | 2 | vF. vS. stellar. 300. |
| 628 | | —— —— | p | 16 | 48 | f | 0 | 9 | 1 | cF. cS. |
| 629 | | —— —— | p | 15 | 24 | f | 0 | 8 | 1 | Two. Both vF. vS. dist. 3′, nearly mer. 300. |
| 630 | | | | | | | | | | |
| 631 | | 34 (μ) Urſæ | f | 3 | 39 | f | 1 | 55 | 2 | vF. S. R. 300. |
| 632 | | 47 —— | p | 2 | 8 | n | 0 | 32 | 2 | cF. vS. lE. mer. gmbM. |
| 633 | | 20 Canum | f | 1 | 58 | f | 0 | 13 | 1 | vF. S. lbM. |
| 634 | | 54 (φ) Bootis | p | 1 | 24 | f | 0 | 36 | 1 | vF. vS. conf. 300 ſp. 2 vBſt. |
| 635 | | —— —— —— | f | 6 | 42 | n | 0 | 46 | 1 | Two. The nf. vF. vS. verif. 300. |
| 636 | | | | | | | | | | The ſp. diſcov. with 300 eF. S. iF. |
| 637 | | 30 (ζ) Hercul | p | 24 | 18 | f | 1 | 5 | 1 | vF. eS. 300. ſhewed 2vSſt. with nebu. |
| 638 | | —— —— —— | p | 3 | 33 | f | 0 | 59 | 1 | vF. vS. |
| 639 | | —— —— —— | p | 2 | 53 | f | 1 | 24 | 1 | eF. eS. |
| 640 | | —— —— —— | f | 0 | 54 | f | 1 | 5 | 1 | vF. vS. |
| 641 | | —— —— —— | f | 1 | 10 | f | 1 | 10 | 1 | vF. vS. |
| 642 | 19 | 70 Virginis | f | 1 | 37 | f | 0 | 26 | 1 | vF. S. iF. time l. inaccurate. |
| 643 | | —— —— | f | 3 | 43 | n | 0 | 5 | 1 | vF. S. lE. juſt ff. ſt. |
| 644 | | 5 (ν) Bootis | f | 25 | 41 | f | 0 | 44 | 1 | vF. vS. E. confir. 300. |
| 645 | | 30 (ζ) —— | p | 10 | 16 | n | 0 | 17 | 1 | eF. vS. lbM. betw. 2 vFſt. 300. |
| 646 | | 28 (β) Serpen | f | 11 | 15 | n | 0 | 24 | 1 | vF. S. lE. |
| 647 | 20 | 44 Lyncis | p | 33 | 11 | f | 2 | 16 | 1 | vF. vS. verif. 300. |
| 648 | | 13 Canum | p | 36 | 41 | n | 0 | 46 | 1 | vF. E. par. 1′ l. |
| 649 | | —— —— | f | 12 | 29 | n | 1 | 0 | 1 | vF. S. lE. |
| 650 | | —— —— | f | 19 | 54 | n | 2 | 18 | 1 | eF. vS. |
| 651 | | —— —— | f | 27 | 11 | n | 1 | 11 | 1 | vF. S. |
| 652 | | —— —— | f | 29 | 47 | n | 0 | 17 | 1 | eF. vS. |
| 653 | | —— —— | f | 62 | 59 | n | 1 | 34 | 1 | vF. pS. E. mer. 300. |
| 654 | April 9 | 19 —— | p | 7 | 30 | n | 0 | 51 | 1 | vF. vS. lbM. |
| 655 | | —— —— | p | * | 26 | n | 2 | 57 | 1 | vF. pS. lbM. *forgot, but is 5, 6, or 7′. |
| 656 | | 20 —— | f | 15 | 21 | n | 1 | 15 | 1 | vF. vS. lbM. |
| 657 | | —— —— | f | 83 | 33 | n | 1 | 57 | 1 | Two. Both vF. vS. E. in differ. directions. 2 or 3′ dist. par. each ſ. Sſt. |
| 658 | | | | | | | | | | |
| 659 | | —— —— | f | 117 | 16 | n | 0 | 18 | 1 | vF. vS. r. |
| 660 | | —— —— | f | 119 | 18 | n | 1 | 16 | 1 | eF. cS. |
| 661 | | —— —— | f | 125 | 25 | n | 0 | 44 | 1 | eF. S. |
| 662 | 11 | 29 (γ) Virgin | f | 2 | 8 | n | 0 | 54 | 1 | vF. pL. |
| 663 | | —— —— —— | f | 3 | 33 | n | 0 | 55 | 1 | vF. S. iF. |
| 664 | | —— —— —— | f | 6 | 6 | f | 0 | 14 | 1 | vF. S. |
| 665 | 15 | 90 (ρ) —— | p | 1 | 48 | n | 0 | 23 | 2 | cF. cL. R. vlbM. r. 5′ dia. |
| 666 | | 102 (1ſt ν) — | p | 19 | 18 | f | 0 | 55 | 1 | eF. vS. |
| 667 | | —— —— —— | p | 18 | 53 | f | 0 | 33 | 2 | eF. vS. verif. 300. 2d obſ. vF. S. |
| 668 | | 105 (φ) —— | p | 3 | 29 | f | 0 | 58 | 1 | cF. S. r. |
| 669 | May 7 | 61 —— | p | 5 | 42 | n | 1 | 30 | 1 | vF. |
| 670 | | —— —— | p | 2 | 45 | n | 1 | 46 | 1 | vF. |
| 671 | | 8 Libræ | p | 9 | 38 | f | 1 | 28 | 1 | cF. S. R. ſp and joining 2Sſt. |

| III. | 1787 | | Stars. | | M. | S. | | D.M. | Ob | | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 672 | May | 12 | 19 (*h*) Bootis | p | 48 | 58 | n | 0 41 | 3 | | cF. vS. ſtellar. 300. |
| 673 | | | —— —— —— | p | 38 | 30 | n | 2 21 | 1 | | cF. S. R. or lE. |
| 674 | | | —— —— —— | p | 5 | 52 | n | 2 31 | 1 | | cF. cS. iR. |
| 675 | | | 38(2d *b*) —— | p | 11 | 18 | n | 0 35 | 1 | | vF. pS. iF. ſp. 2 S. unequal ſt. |
| 676 | | 15 | 24 (*g*) —— | p | 16 | 34 | n | 0 35 | 2 | | cF. cS. lE nearly par. |
| 677 | | | —— —— —— | p | 2 | 56 | ſ | 1 15 | 1 | | vF. pS. lE. |
| 678 | | | *A Bootis 7m | f | 0 | 3 | n | 0 3 | 1 | | Two. The p. vF. vS. The f. |
| 679 | | | —— | f | 0 | 48 | n | 0 1 | | | eF. eS. * See note. |
| 680 | | | 42 Herculis | p | 13 | 17 | n | 1 0 | 2 | | vF. S. R. lbM. er. near ſome Sſt. |
| 681 | | 16 | * C Can. 6m. | f | 0 | 44 | ſ | 0 15 | 1 | | cF. vS. lE. * See note. |
| 682 | | | —— —— —— | f | 7 | 35 | ſ | 0 7 | 1 | | eF. cS. E. ſp. Sſt. |
| 683 | | | —— —— —— | f | 12 | 35 | ſ | 0 25 | 1 | | cF. pL. iF. |
| 684 | | | —— —— —— | f | 13 | 49 | n | 0 34 | 1 | | vF. vS. R. |
| 685 | | | 27 (*γ*) Bootis | p | 19 | 48 | n | 1 6 | 2 | | vF. cS. R. ſbM. |
| 686 | | | —— —— —— | f | 8 | 42 | n | 0 18 | 1 | | eF. cS. lbM. |
| 687 | | | —— —— —— | f | 13 | 27 | n | 0 23 | 1 | | cF. pS. another ſuſpec. 2′ n. 300. |
| 688 | | | 16(*τ*) Coronæ | f | 7 | 34 | ſ | 0 48 | 1 | | vF. cS. iR. |
| 689 | | | 67 (*π*) Hercu | p | 20 | 32 | ſ | 0 11 | 1 | | eF. cL. iE. nearly par. |
| 690 | | 19 | 10 Libræ | p | 4 | 6 | ſ | 0 43 | 1 | | vF. cS. iF. lbM. |
| 691 | | | —— —— —— | f | 6 | 51 | ſ | 0 59 | 1 | | cF. ſmbM. ſtellar. |
| 692 | Aug. | 12 | 33 (*ι*) Aquarii | p | 5 | 23 | n | 0 38 | 1 | | eF. E. np ff. 2′ l. 1′ b. |
| 693 | Sept. | 11 | 41 —— | p | 11 | 30 | n | 0 36 | 1 | | eF. vS. 360 confirmed it. |
| 694 | Oct. | 11 | 50 (*f*) Caſſio | f | 90 | 22 | n | 0 30 | 1 | | vF. vS. iR. bM. |
| 695 | Nov. | 3 | 10 Camelop | p | 155 | 0 | n | 0 53 | 1 | | eF. pL. iF. |
| 696 | | 5 | 17 (*ξ*) Cephei | p | 10 | 35 | ſ | 0 47 | 2 | | vF. S. R. lbM. r. 1′ dia. |
| | 1788 | | | | | | | | | | |
| 697 | Jan. | 14 | 67 Urſæ | f | 11 | 9 | n | 0 40 | 3 | | vF. E. np ff. 5′ l. 1′ b. |
| 698 | | | 27 (*γ*) Bootis | p | 39 | 53 | n | 1 29 | 2 | | vF. S. |
| 699 | | | —— —— —— | p | 38 | 20 | n | 2 8 | 2 | | vF. S. iF. |
| 700 | Feb. | 3 | 45 (*ω*) Urſæ | p | 14 | 53 | ſ | 1 33 | 1 | | cF. L. iE. mb. f. M. 4′ l. 2′½ b. |
| 701 | | | —— —— —— | p | 6 | 6 | ſ | 0 1 | 1 | | vF. vS. iF. |
| 702 | | | 13 Canum | p | 42 | 13 | ſ | 0 55 | 1 | | vF. vS. |
| 703 | | 5 | 71(*σ*) Gemin. | p | 10 | 3 | ſ | 0 46 | 1 | | vF. vS. perhaps a patch of ſt. |
| 704 | | | 60 Urſæ | p | 81 | 11 | ſ | 0 22 | 1 | | eF. vS. perhaps a patch of Sſt. |
| 705 | | | —— —— —— | p | 39 | 57 | ſ | 0 43 | 1 | | vF. |
| 706 | | | —— —— —— | p | 23 | 49 | n | 0 38 | 2 | | vF. vS. lE. f. cBſt. |
| 707 | | | 63(*χ*) —— | f | 11 | 2 | n | 0 34 | 2 | | vF. vS. another ſuſp. ff. eF. eS. |
| 708 | | 6 | 59 —— | f | 30 | 14 | ſ | 0 31 | 1 | | vF. vS. in a line with 2 ſt. nf ſp. |
| 709 | March | 9 | 21 Lyncis | f | 34 | 50 | n | 1 41 | 1 | | vF. R. vgbM. 2′½ dia. |
| 710 | | | 9 (*ι*) Urſæ | p | 45 | 51 | n | 0 49 | 1 | | vF, iF. 2′½ l. 1′½ b. |
| 711 | | | —— —— —— | p | 41 | 10 | n | 1 49 | 1 | | eF. E. ſp nf. 3′½ l. 2′½ b. |
| 712 | | | —— —— —— | p | 4 | 49 | n | 1 6 | 1 | | eF. cS. r. p. ſome Fſt. |
| 713 | | | —— —— —— | f | 25 | 7 | n | 1 15 | 1 | | cF. cS. lE. |
| 714 | | | —— —— —— | f | 24 | 58 | n | 1 11 | 1 | | eF. cS. lE. |
| 715 | | | 63 (*χ*) —— | f | 3 | 26 | n | 0 39 | 1 | | cF. pS. |

| III. | 1787 | Stars. | | M. | S. | | D.M. | | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 716 | March 9 | 63 (χ) Urſæ | f | 5 | 2 | n | 2 | 26 | 1 | vF. vS. |
| 717 | — | 3 Canum | p | 14 | 1 | n | 0 | 37 | 1 | cF. mE. nearly mer. 5′ l. |
| 718 | — | — — | p | 4 | 6 | ſ | 0 | 51 | 1 | vF. vS. |
| 719 | — | — — | p | 2 | 47 | ſ | 1 | 31 | 1 | Two. Both vF. vS. diſt. 1′ in the ſame meridian. |
| 720 | — | — — | | | | | | | | |
| 721 | — | — — | f | 32 | 1 | ſ | 1 | 21 | 1 | vF. S. |
| 722 | 11 | 49 (g) Virgin | p | 18 | 9 | ſ | 0 | 21 | 1 | eF. S. |
| 723 | April 1 | Neb. II. 728. | p | 0 | 25 | ſ | 0 | 2 | 1 | eF. vS. |
| 724 | 8 | 61 Virginis | f | 1 | 43 | ſ | 2 | 23 | 1 | cF. vS. iF. |
| 725 | 10 | 60 Urſæ | f | 39 | 40 | ſ | 1 | 14 | 2 | eF. cL. iR. lbM. 3′ dia. |
| 726 | — | — — | f | 42 | 45 | ſ | 0 | 34 | 2 | vF. pS. R. |
| 727 | 12 | 35 (σ) Hercul | f | 16 | 11 | n | 0 | 14 | 1 | cF. S. E. par. |
| 728 | 13 | 42 — | f | 20 | 46 | n | 0 | 54 | 1 | vF. cS. iR. |
| 729 | 27 | 19 (λ) Bootis | p | 113 | 28 | ſ | 0 | 3 | 1 | vF. S. |
| 730 | 28 | 27 (β) Hercul | f | 4 | 6 | n | 0 | 2 | 1 | eF. vS. E. |
| 731 | 29 | 27 (γ) Bootis | p | 15 | 47 | n | 1 | 16 | 1 | vF. vS. |
| 732 | — | — — — | p | 15 | 33 | n | 1 | 22 | 1 | vF. vS. lE. |
| 733 | — | — — — | p | 9 | 25 | n | 2 | 4 | 1 | vF. vS. |
| 734 | — | — — — | p | 8 | 52 | n | 2 | 8 | 1 | cF. pS. |
| 735 | — | 22 (τ) Hercul | f | 30 | 17 | ſ | 1 | 2 | 1 | eF. pS. with 300 iF. |
| 736 | 30 | 23 (1ſt) Libr | f | 7 | 7 | n | 1 | 59 | 1 | vF. pL. E. mer. lbM. 300. |
| 737 | May 1 | 23 (δ) Bootis | f | 49 | 59 | ſ | 1 | 46 | 1 | vF. vS. ſtellar. |
| 738 | 25 | 12 (ι) Draco | f | 17 | 8 | n | 0 | 44 | 1 | vF. vS. |
| 739 | June 2 | 14 (ε) — | p | 32 | 30 | n | 0 | 57 | 1 | vF. R. vgbM. er. 3′ dia. |
| 740 | 3 | 15 (A) — | p | 10 | 14 | ſ | 3 | 21 | 1 | cF. pL. iE. |
| 741 | 6 | 31 (1ſt ♈) — | p | 5 | 13 | ſ | 0 | 5 | 1 | eF. ſtellar. with 300 lE. par. |
| 742 | July 8 | *B Draco 7m. | f | 4 | 25 | ſ | 0 | 27 | 1 | vF. ſtellar. verif. 300. * See note. |
| 743 | 30 | 19 Aquilæ | f | 9 | 24 | n | 0 | 26 | 1 | cF. iR. r. 3 or 4″ dia. |
| 744 | Aug. 2 | 51 — | p | 8 | 8 | n | 0 | 29 | 1 | vF. pL. R. vgmbM. |
| 745 | Nov. 1 | 27 (ϑ) Cephei | f | 26 | 10 | f | 1 | 24 | 1 | vF. pL. iF. er. |
| 746 | — | 36 Camelop. | f | 64 | 5 | ſ | 0 | 38 | 1 | vF. S. R. lbM. |
| 747 | Dec. 3 | *22 Cam Hev | p | 37 | 1 | ſ | 0 | 8 | 1 | cF. pL. iF. mbM. er. ſome ſt. viſible. * See note. |

## Fourth claſs. Planetary nebulæ.

Stars with burs, with milky chevelure, with ſhort rays, remarkable ſhapes, &c.

| IV. | 1785 | Stars. | | M. | S. | | D.M. | | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | May 1 | 14 Canum | p | 6 | 48 | | 0 | 55 | 2 | Two ſt. diſt. 3′ connected with a vF. narrow nebuloſity. |
| 31 | Oct. 3 | 50 Aquarii | f | 7 | 55 | | 0 | 37 | 1 | F. S. ſtellar. with pL. chev. |
| 32 | 5 | 62 (b) Eridani | f | 0 | 35 | n | 0 | 21 | 2 | vB. vS. mbM. like a ſt. affected with irregular burs. |
| 33 | — | 49 (d) Orion | p | 2 | 33 | n | 0 | 28 | 4 | A ſt. with m. chev. or vBN. with m. nebuloſity. |

| IV. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 34 | Dec. 28 | 40(2dρ) Orio | f | 5 | 41 | s | 0 | 12 | 2 | cB. S. nearly R. like a st. with L. dia. with 240 like an ill defined planetary neb. |
| 35 | 31 | 9 Hydræ | p | 8 | 19 | s | 0 | 14 | 1 | A S st. with a brush sp. FS. it resembles fig. 7. Phil. Trans. Vol. LXXIV. Tab 17. |
| 36 | 1786 Jan. 1 | 60 Orionis | p | 11 | 38 | s | 0 | 20 | 3 | A st. affected with vF. extensive m. chev. The st. not quite central. |
| 37 | Feb. 15 | 28 (ω) Draco | f | 20 | 33 | s | 2 | 12 | 1 | A planetary neb. vB. has a disk of about 35″ dia. but very ill defined edge. With long attention a vB. well defined R. center becomes visible. |
| 38 | 24 | 55 Orionis | f | 18 | 3 | n | 1 | 17 | 2 | A cst. affected with vF. m. chev. |
| 39 | March 19 | 2 Navis | p | 3 | 32 | s | 0 | 5 | 1 | pB. R. r. within the 46th of the *Connoiss. des Temps* almost of an equal light throughout 2′ dia. no connection with the cluster, which is free from nebulosity. |
| 40 | 27 | 68 (ι) Virgin | p | 30 | 45 | s | 0 | 18 | 1 | A pBst. with a seeming brush to it np. may be a vS neb. close to it. |
| 41 | May 26 | 14 Sagittarii | p | 11 | 58 | s | 1 | 15 | 1 | A double st. with extensive nebulosity of different intensity. About the double st. is a black opening resembling the neb. in Orion in miniature. |
| 42 | Sept. 30 | 51 Ceti | f | 7 | 26 | n | 0 | 27 | 1 | A st. about 8 or 9 m. with vF. branches each branch 1′ l. |
| 43 | Oct. 17 | 26 (β) Persei | p | 2 | 48 | n | 1 | 54 | 2 | A pBst. with 2 F. branches. |
| 44 | Nov. 28 | 5 Monocero | p | 7 | 16 | s | 0 | 2 | 1 | A st. involved in m. chev. |
| 45 | 1787 Jan. 17 | 55 (J) Gemin | f | 9 | 6 | s | 1 | 1 | 2 | A st. 9 m. with a pR. m. nebulosity. equally dispersed all around. A very remarkable phænomenon. |
| 46 | Feb. 22 | 99 (ι) Virgin | p | 4 | 38 | n | 0 | 57 | 1 | pB almost cB. vS. stellar. like a star with burs. |
| 47 | March 11 | 44 (ℓ) —— | f | 1 | 48 | s | 0 | 46 | 1 | pB. stellar. resembles a st. with a bur all around. |
| 48 | 18 | 19 Leo. min | f | 6 | 32 | s | 0 | 17 | 1 | A vFst affected with vF. nebulosity. E. sp nf. 1′ l. 300 |
| 49 | April 15 | 102 (1st ν) Vir | p | 6 | 9 | s | 0 | 52 | 2 | pB stellar. like a st. with a S. bur all around. |
| 50 | May 12 | 77 (ο) Hercul | p | 40 | 13 | s | 0 | 38 | 1 | vB. R. 4′ dia. almost equally B. with a F. r. margin. |

| IV. | 1787 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 51 | Aug. 8 | 61 (*g*) Sagitt | p | 13 | 56 | n | 1 | 23 | 2 | A cB. S. beautiful planetary nebula; but c. hazy on the edges, of a uniform light; 10 or 15″ dia. perfectly R. I ſhewed it to M. DE LA LANDE. |
| 52 | Nov. 3 | 4 (*d*) Caſſio | p | 4 | 0 | ſ | 1 | 6 | 2 | A ſt. 9 m. with vF. nebulosity of S. extent about it. |
| 53 | — | 10 Camelop | p | 55 | 42 | n | 0 | 11 | 2 | A pB. planetary nebula. near 1′ dia. R. of uniform light and pretty well defined. 2 obſ. with 360 magnified in proportion; but ſtill pretty abruptly defined, and a little elliptical. |
| | 1788 | | | | | | | | | |
| 54 | Jan. 14 | 67 Urſæ | f | 7 | 32 | ſ | 0 | 30 | 1 | cB. S. N. with F. chev. |
| 55 | Feb. 6 | 34 Lyncis | p | 28 | 4 | n | 0 | 2 | 2 | pB. R. almoſt of an even light throughout, approaching to planetary, but ill defined and a little fainter on the edges ½ or 1′ dia. p. 1′ pc ſt. |
| 56 | — | 59 Urſæ | f | 25 | 11 | n | 0 | 56 | 1 | cB. iR. cBNM. with extenſive chev. 5′ dia. |
| 57 | June 11 | 35 (*e*) Hercul | f | 34 | 27 | ſ | 0 | 18 | 2 | AvS.F.ſt involved in eF. nebulosity. |
| 58 | Nov. 25 | 24 Cephei | f | 116 | 28 | n | 0 | 2 | 1 | A ſt. 9 m. ſurrounded with vF. m. nebulosity. The ſt. is either double, or not R. Leſs than 1′ dia. |

## Fifth claſs. Very large nebulæ.

| V. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | Nov. 27 | 18 Ceti | f | 1 | 30 | n | 1 | 2 | 1 | Four or five pL. ſt. forming a trapezium of about 5′ dia. The incloſed ſpace is filled up with faintly terminated m. nebulosity. The ſt. ſeem to have no connexion with the nebulosity. |
| 26 | Dec. 7 | 18 Leo. min. | p | 8 | 7 | n | 1 | 1 | 2 | cR. mE. par. 8′ l. 3′ b. |
| 27 | 26 | 15 Monocero | p | 0 | 12 | f | 0 | 6 | 2 | Some pBſt 7 or 8′ ſp. 15th Monoc. are involved in eF. m. nebulosity which loſes itſelf imperceptibly. |
| | 1786 | | | | | | | | | |
| 28 | Jan. 1 | 48 (*o*) Orion | f | 2 | 46 | n | 0 | 44 | 2 | Remarkable m. nebulosity, divided in 3 or 4 large patches, including a dark ſpace; cannot |

| V. | 1786 | | Stars. | | M. | S. | | D.M. | | ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | take up leſs than ½ degree, but I ſuppoſe it to be much more extenſive. |
| 29 | | 2 | 61 Urſæ | f | 45 | 38 | ſ | 0 | 40 | 1 | eF. vL. vlbM. r. 10′ l. 8 or 9′ b. |
| 30 | | 18 | 42, 45 } c Orionis | p | 0 | 0 | n | 0 | 0 | 2 | The 1ſt and 2d c Orionis, and the ſtars about them, are involved in eF. unequally B. m. nebuloſity. |
| 31 | | 31 | 44 (ι) —— | p | 0 | 0 | n | 0 | 0 | 2 | Orionis with its neighbouring ſt. are involved in eF. m. nebuloſity to a great extent. |
| 32 | Feb. | 1 | 28 (κ) —— | p | 17 | 26 | ſ | 1 | 4 | 2 | cB. vL. m. diffuſed and vaniſhing. near and ff. Bſt. |
| 33 | | | —— — —— | f | 1 | 26 | ſ | 0 | 7 | 1 | Diffuſed eF. m. nebuloſity. The means of verifying this phænomenon are difficult. |
| 34 | | | —46(ι) Orionis | p | 0 | 0 | n | 0 | 0 | 1 | I am pretty certain ι Orionis is involved in unequally diffuſed m. nebuloſity. |
| 35 | | | —36 (ν) —— | f | 3 | 39 | ſ | 0 | 40 | 4 | Diffuſed m. nebuloſity, extending |
| | | | 56 —— | p | 2 | 16 | n | 0 | 28 | | over no leſs than 10 degrees of PD. and many degrees of RA. It is of very different brightneſs, and in general extremely F. and difficult to be perceived. Muſt probably the nebuloſities of the 28th, 30, 31, 33, 34, and 38th of this claſs are connected together, and form an immenſe ſtratum of far diſtant ſtars, to which muſt alſo belong the nebula in Orion. |
| 36 | Oct. | 17 | 35 (ι) Andro | p | 9 | 8 | ſ | 0 | 20 | 2 | vF. vL. E. nearly mer. or a little from np ff. about 20′ l. |
| 37 | | 24 | 57 Cygni | f | 5 | 1 | ſ | 1 | 1 | 1 | vL. diffuſed nebuloſity. bM. 7 or 8′ l. 6′ b. and loſing itſelf vg. and imperceptibly. |
| 38 | Dec. | 20 | 19 (β) Orion | f | 11 | 9 | n | 1 | 19 | 1 | Strongly ſuſpected nebuloſity of v. great extent. Not leſs than 2°11′ of PD. and 26″ of RA. in time. |
| | | | | | 11 | 35 | ſ | 0 | 52 | | |
| 39 | | 21 | 11 (β) Crater | p | 8 | 15 | ſ | 0 | 17 | 2 | vF. mE. nearly par. or about 10° ſp nf, vgbM. 8′ l. 3′ b. |

| V. | 1786 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | Dec. 21 | 11 (β) Crater | p | 7 | 49 | f | 0 | 26 | 2 | vF. mE. 15° sp nf. vlbM. about 7′ l. 4′ b. |
| | 1787 | | | | | | | | | |
| 41 | March 17 | 6 Canum | p | 8 | 27 | f | 1 | 12 | 1 | vB. E. 60° sp nf. 20′ l. 2′ b. |
| 42 | 20 | 13 —— | p | 18 | 39 | n | 1 | 48 | 1 | vB. mE. sp nf. but nearly par. mbM. 16′ l. |
| | 1788 | | | | | | | | | |
| 43 | March 9 | 3 —— | p | 0 | 38 | f | 1 | 41 | 3 | v brilliant. BN. with Fm. bran. npff. 15′ l. and to the ff. running into vF. nebulosity extending a great way. the N. is not R. |
| 44 | Nov. 1 | 36 Camelop | f | 84 | 33 | n | 0 | 23 | 2 | cB. R. vgbM. BN. 6 or 7′ dia. with a F. branch extending a great way to the np. side, not less than ½ degree. and to the n. or nf. the nebulosity diffused over a space not less than a whole degree. |

## Sixth class. Very compressed and rich clusters of stars.

Additional abbreviations. } Cl. Cluster. st. scattered. com. compressed. co. coarsely.

| VI | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Oct. 27 | 18(ι) Pisc. Aust | f | 133 | 24 | n | 0 | 23 | 2 | cB. iR. 8 or 9′ dia. a great many of the st. visible, so that there can remain no doubt but that it is a Cl. of vS. stars. |
| 21 | Dec. 7 | 25 Gemino | f | 2 | 15 | f | 1 | 15 | 1 | A v. rich and v. com. Cl. st. of about 5′ dia. some of the largest st. are in a row. |
| | 1786 | | | | | | | | | |
| 22 | Feb. 1 | 31 Monocero | p | 30 | 4 | n | 1 | 20 | 4 | A beautiful Cl. of much com. st. consid. rich. 10 or 12′ dia. C. H. discovered it in 1783. |
| 23 | June 27 | 46 (υ) Sagitt | p | 49 | 25 | f | 0 | 42 | 1 | A beautiful Cl. of vS. st. of various sizes. 15′ dia. very rich. |
| 24 | Oct. 17 | 58 (γ) Cygni | f | 15 | 56 | n | 1 | 18 | 2 | A v. com. and v. rich Cl. of eSt. about 6′ l. 4′ b. nearly par. |
| 25 | Dec. 13 | 27 (κ) Persei | f | 5 | 55 | n | 2 | 25 | 2 | A beautiful com. and rich Cl. of S. and L. st. 7 or 8′ dia. the L. st. arranged in lines like interwoven letters. |

| VI. | 1786 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 | Dec. 11 | 53 (*d*) Perſei | f | 13 | 34 | f | 1 | 13 | 1 | A vF. and v. com. Cl. of eS. ſt. near 4′ dia. |
| 27 | 27 | 22 Monocero | p | 20 | 9 | n | 0 | 51 | 1 | A v. beautiful Cl. of much com. S. and L. ſt. above 20′ dia. |
| | 1787 | | | | | | | | | |
| 28 | Jan. 11 | 75 (*l*) Orionis | f | 21 | 25 | n | 1 | 2 | 1 | A Cl. of e. com. and eS. ſt. c. rich iF. the f. and moſt com. part R. |
| 29 | Oct. 14 | 3 Lacertæ | p | 7 | 52 | n | 2 | 7 | 1 | A com. Cl. of eS. ſt. |
| 30 | 18 | 7 (ε) Caſſiop | f | 3 | 10 | f | 0 | 46 | 3 | A beautiful Cl. of v. com. Sſt. v. rich. C. H. diſcovered it 1783. |
| 31 | Nov. 3 | 37 (*J*) —— | f | 19 | 48 | n | 1 | 2 | 1 | A beautiful Cl. of pL. ſt. near 15′ dia. conſ. rich. |
| | 1788 | | | | | | | | | |
| 32 | Sept. 21 | 80 (1ſt π) Cyg | p | 11 | 26 | n | 0 | 28 | 1 | A beautiful Cl. of p. com. ſt. 8 or 9′ dia. nearly R. c. rich. |
| 33 | Nov. 1 | 7 (χ) Perſei | f | 1 | 7 | f | 0 | 22 | 1 | A v. beautiful and brilliant Cl. of L. ſt. v. rich. the M. contains a vacancy. |
| 34 | | —— —— —— | f | 4 | 0 | f | 0 | 23 | 1 | A v. beautiful, brilliant Cl. of L. ſt. iR. v. rich. near ½ degree in dia. |
| 35 | 26 | 15 (κ) Caſſiop | p | 1 | 22 | f | 1 | 26 | 1 | A S. Cl. of vF. and e. com. ſt. about 1′ dia. The next ſtep to an er. neb. |

## Seventh claſs. Pretty much compreſſed cluſters of large or ſmall ſtars.

| VII. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | July 17 | 12 Vulpeculæ | p | 7 | 56 | n | 0 | 44 | 1 | An E. Cl. of i. ſc. ſt. of various ſizes, c. rich. |
| 19 | 30 | 21 Aquilæ | p | 5 | 49 | n | 1 | 55 | 1 | A p. com. Cl. of p. ſc. ſt. of var. ſizes, magnitudes, and colours. iF. and unequally com. 12 or 15′ dia. |
| 20 | Nov. 1 | 7 Monocero | f | 1 | 3 | n | 0 | 35 | 3 | A beautiful Cl. of p. com. and equally ſc. ſt. 10 or 12′ dia. |
| 21 | Dec. 26 | 109 (*n*) Tauri | p | 14 | 59 | n | 1 | 37 | 1 | A Cl. of p com. ſt. with many eS. ſt. mixed with them. |
| 22 | 28 | 3 Monocero | f | 2 | 48 | n | 0 | 21 | 1 | A S. Cl. of p. com. vS. ſt. |
| 23 | 30 | 31 (ν) Canis | f | 32 | 6 | ſ | 0 | 39 | 1 | A com. Cl. of pL. ſt. c. rich. |
| | 1786 | | | | | | | | | |
| 24 | Jan. 1 | 60 Orionis | p | 5 | 9 | f | 0 | 9 | 2 | A Cl. of p. com. pS. ſc. ſt. with many eS. ſuſpec. betw. them 7 or 8′ dia. |
| 25 | 27 | 8 Monocero | p | 11 | 46 | n | 0 | 49 | 1 | A Cl. of p. com. ſt. of ſeveral ſizes 4 or 5′ dia. with extenſively ſtraggling ones. |

| VII. | 1786 | Stars. | | M. | S. | | D.M. | | Ob | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 | Jan. 30 | 6 Monocero | f | 8 | 59 | n | 1 | 7 | 1 | A Cl. of eS and pm. com. ſt. with a few L. but not rich. in the ſhape of a hook. |
| 27 | Feb. 24 | 11 —— | f | 42 | 13 | ſ | 1 | 21 | 2 | An i. Cl. of eS. ſt. c. com. 9 or 10′l. 4 or 5′ b. with an extending bran. towards ſp. C. H. diſcov. 1783. |
| 28 | Mar. 19 | 2 Navis | p | 8 | 23 | n | 0 | 47 | 1 | A Cl. of pS. ſt. p. rich. 15′ dia. |
| 29 | April 30 | 5 (ε) Scorpii | p | 7 | 14 | n | 0 | 38 | 1 | A Cl. of vS. ſt. p. rich 6′l. 4′b. in the form of a parallelogram. |
| 30 | May 26 | 14 Sagittarii | p | 1 | 35 | n | 0 | 9 | 1 | A Cl. of pS. ſc. ſt. above 15′ dia. |
| 31 | —— —— | —— | f | 1 | 29 | ſ | 0 | 25 | 1 | A Cl. of vS. and p. com. ſt. c. rich. 2 or 3′ dia. |
| 32 | Sept. 21 | 58 Androm | p | 10 | 49 | ſ | 0 | 8 | 4 | A vL. co. ſc. Cl. of vL. ſt. iR v. rich. takes up ¼ degree like a nebulous ſt. to the naked eye. |
| 33 | Oct. 18 | 11 (μ) Aurig | f | 6 | 32 | n | 0 | 54 | 1 | A Cl. of p. com. pS. Sſt. c. rich. contains 1 L. the reſt are all of a ſize. |
| 34 | Dec. 11 | 13 (α) —— | f | 9 | 7 | n | 0 | 32 | 1 | A Cl. of vF. and vSſt. p. com. but not rich. iF. 3′ dia. |
| 35 | | 24 70(ξ) Orionis | f | 15 | 53 | ſ | 1 | 29 | 1 | A Cl. of S. pm. com. ſt. with ſuſpected m. nebuloſity. |
| 36 | | 26 18 Monocero | p | 3 | 48 | n | 1 | 0 | 1 | A Cl. of v. ſc. ſt. c. rich. and of great extent. |
| 37 | | 27 77 Orionis | f | 12 | 24 | n | 0 | 55 | 1 | A Cl. of v. com. eSſt. c. rich. 3 or 4′ dia. moſt com. M. |
| 38 | | —22 Monocero | p | 7 | 39 | n | 1 | 31 | 2 | A beautiful Cl. of vSſt. of ſeveral ſizes. c. com. and rich M. 10 or 12′ dia. |
| | 1787 | | | | | | | | | |
| 39 | Jan. 17 | 21(σ) Aurigæ | f | 3 | 25 | ſ | 2 | 6 | 1 | A p. com. Cl. of Sſt. 4′ dia. |
| 40 | Oct. 14 | 3 Lacertæ | p | 38 | 31 | n | 1 | 35 | 1 | A Cl. of Sſt. of ſeveral ſizes. 3 or 4′ dia. p. rich. like a forming one. |
| 41 | | —— —— | f | 5 | 8 | n | 0 | 2 | 2 | A S Cl. of ſt. p. com. c. rich in vS. ſt. The com. part 4 or 5′ dia. |
| 42 | | 18 24 (κ) Caſſio | f | 29 | 41 | n | 0 | 26 | 2 | A brilliant Cl. of L. and vS. ſt. c. rich. |
| 43 | Nov. 3 | 1 (ε) —— | p | 11 | 41 | n | 1 | 25 | 1 | A S. Cl. of vSſt. c. com. and p. rich. |
| 44 | | —— — — | f | 4 | 34 | n | 1 | 8 | 2 | A Cl. of p com. pLſt. c. rich. The ſt. arranged chiefly in lines from ſp. nf. |
| 45 | | —37 (ϑ) —— | p | 9 | 29 | ſ | 1 | 28 | 2 | A S. p. com. Cl. of ſt. not rich. iF. like a forming one. |
| 46 | | —— — — | f | 17 | 23 | n | 1 | 44 | 2 | A S. Cl. of pL. ſt. c. rich. |
| 47 | | —10 Camelop | p | 55 | 40 | n | 1 | 37 | 2 | A Cl. of ſt. p. rich and c. com. iE. 3 or 4′ dia. iF. |

| VII. | 1787 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 48 | Nov. 9 | 32 Caſſiop | f | 17 | 1 | ſ | 1 | 40 | 1 | A com. Cl. of ſome pL. and many vS. ſt. iR. 6 or 7′ dia. |
| 49 | — | 45 (ι) — | p | 11 | 8 | n | 0 | 20 | 1 | A Cl. of ſome cL. ſt. and many eS. ſo as hardly to be ſeen. The Lſt. arranged in circular order 3 or 4′ dia. |
| | 1788 | | | | | | | | | |
| 50 | Sept. 27 | 81(2d ♒)Cyg | p | 22 | 13 | ſ | 1 | 14 | 1 | A few Sſt. with ſuſpected nebuloſity, with 300 many vS. ſt. intermixed with the former, ſo as to make a Cl. |
| 51 | Oct. 19 | 71 (ℊ) — | p | 5 | 49 | ſ | 0 | 9 | 1 | A p. com. Cl. of pS. ſt. c. rich iR. 5 or 6′ dia. |
| 52 | — | — — — | p | 0 | 42 | n | 0 | 34 | 1 | An extenſive Cl. of Lſt. c. rich above 20′ dia. |
| 53 | — | 73 (ι) — | f | 30 | 41 | n | 0 | 48 | 2 | A L. Cl. of p. com. cLſt. above 15′ dia. c. rich. |
| 54 | Nov. 1 | 36 Camelop | f | 29 | 1 | n | 0 | 16 | 1 | A vF. patch. or S. Cl. of eSſt. |
| 55 | 23 | 32 (ι) Cephei | f | 57 | 34 | n | 1 | 47 | 3 | A Cl. of cS. ſt. iF. p. rich and com. contains a vacancy M. |

## Eighth claſs. Coarſely ſcattered cluſters of ſtars.

| VIII. | 1785 | Stars. | | M. | S. | | D. | M. | Ob | Deſcription. |
|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Dec. 7 | 98 (ℏ) Tauri | f | 12 | 11 | ſ | 0 | 54 | 1 | A co. Cl. of ſt. or projecting point of the m. way. |
| 42 | — | 125 — | p | 1 | 22 | ſ | 0 | 4 | 2 | A Cl. of co. ſc. ſt. above 15′ dia. The ſt. nearly of a ſize and equally ſc. |
| 43 | 26 | 109 (ν) — | p | 15 | 30 | n | 1 | 29 | 1 | A Cl. of v. co. ſc. Lſt. join. to VII. 21. |
| 44 | 28 | 5 (ν) Can. min | f | 0 | 38 | ſ | 1 | 54 | 1 | A Cl. of v. co. ſc. Lſt. form a croſs. not rich. |
| 45 | 31 | 6 Navis | p | 32 | 48 | ſ | 0 | 1 | 1 | A co. ſc. Cl. of ſt. not rich. |
| 46 | — | — — | p | 10 | 18 | n | 0 | 49 | 1 | A vL. but co. ſc. Cl. of ſt. |
| 47 | — | — — | p | 10 | 27 | n | 0 | 39 | 1 | A Cl. of ſc. ſt. or the m. way crouded with ſt. of equal ſize and colour. |
| | 1786 | | | | | | | | | |
| 48 | Jan. 1 | 78 Orionis | f | 10 | 59 | ſ | 1 | 9 | 1 | A Cl. of v. ſc. ſt. of various ſizes. above ½ degree of extent. |
| 49 | 3 | *B Gemi. 6 m | p | 33 | 23 | n | 0 | 35 | 1 | A Cl. of co. ſc. Lſt. not rich. *See note |
| 50 | 27 | 8 Monocero | f | 10 | 58 | n | 0 | 49 | 2 | A Cl. of ſt. arranged in a broad row. 25′ l. 6 or 8′ b. not v. com. but p. rich. |
| 51 | Feb. 23 | 11 — | f | 25 | 25 | ſ | 0 | 1 | 1 | A Cl. of v. ſc. ſt. |
| 52 | Mar. 19 | 2 Navis | p | 12 | 16 | n | 1 | 32 | 1 | A Cl. of vL. co. ſc. ſt. not rich. |
| 53 | June 27 | 46 (υ) Sagitta | p | 82 | 10 | ſ | 1 | 4 | 1 | A Cl. of ſc. Sſt. 8′ dia. not v. rich. |

| VIII. | 1786 | Stars. | | M. | S. | | D. | M. | Oh | Description. |
|---|---|---|---|---|---|---|---|---|---|---|
| 54 | June 27 | 46 (υ) Sagitta | p | 71 | 19 | f | 0 | 25 | 1 | A co. sc. Cl. of cLst. The place is that of a S. triangle. |
| 55 | — | — — — | p | 64 | 17 | f | 0 | 23 | 1 | A co. sc. Cl. of Lst. |
| 56 | Oct. 17 | 37 (γ) Cygni | f | 0 | 53 | n | 0 | 32 | 1 | A S. Cl. of co. sc. st. of various sizes. E. like a forming one. |
| 57 | — | 58 (•) — | f | 8 | 47 | n | 0 | 20 | 1 | A Cl. of co. sc. pS. st. of several sizes. not rich. |
| 58 | 24 | 57 — | f | 3 | 19 | n | 0 | 16 | 2 | A Cl. of pL. sc. st. not v. rich. |
| 59 | — | 59 Persei | f | 7 | 59 | n | 0 | 21 | 1 | A Cl. of co. sc. pL. st. not v. rich. |
| 60 | Nov. 26 | 19 Monocero | p | 5 | 3 | f | 0 | 23 | 1 | A Cl. of pL. sc. st. not v. rich. may be a projecting point of the m. way. |
| | 1787 | | | | | | | | | |
| 61 | Jan. 17 | 21 (σ) Aurigæ | p | 16 | 38 | f | 0 | 30 | 1 | A Cl. of co. sc. Lst. iF. not rich. like a forming one. |
| 62 | Sept. 19 | 35 (γ) Cephei | p | 4 | 43 | f | 4 | 50 | 2 | A Cl. of co. sc. Lst. not rich. but the st. are brilliant. one 7 m. |
| 63 | Oct. 16 | 21 (ξ) — | f | 1 | 21 | f | 0 | 56 | 1 | A S. Cl. of pL. st. |
| 64 | Nov. 3 | 27 (γ) Cassiop | f | 11 | 12 | n | 0 | 53 | 2 | A forming cluster of p. com. st. C. H. disc. 1783. |
| 65 | — | 37 (ι) — | f | 17 | 56 | n | 0 | 29 | 2 | A S. Cl. of Sst. not v. rich. C. H. 1783. |
| 66 | — | 45 (•) — | f | 47 | 9 | f | 1 | 58 | 2 | A Cl. of co. sc. cLst. 8 or 10′ dia. one 7 m. near M. |
| 67 | 9 | 17 (ξ) Cephei | p | 10 | 0 | f | 2 | 0 | 1 | A Cl. of co. sc. L. and S. st. 7′ dia. like a forming one. |
| 68 | 12 | 41 Aurigæ | p | 8 | 57 | n | 1 | 9 | 1 | A S. Cl. of sc. st. not rich one. 7 m. towards the n. but this does not seem connected with the Cl. |
| 69 | Dec. 3 | 18 Androm | p | 8 | 59 | f | 1 | 20 | 1 | A Cl. of co. sc. pL. st. one 8 m. in the ff. part. |
| | 1788 | | | | | | | | | |
| 70 | Feb. 3 | 41 (υ) Persei | f | 46 | 17 | n | 1 | 28 | 1 | A Cl. of co. sc. Lst. p. rich above 20′ dia. |
| 71 | March 4 | 58 Aurigæ | p | 1 | 22 | f | 0 | 44 | 1 | A Cl. of co. sc. pL. st. p. rich the place is that of a double st. of the 3d class. |
| 72 | July 30 | 62 Serpentis | p | 27 | 26 | n | 0 | 6 | 3 | A Cl. of co. sc. Lst. C. H. 1783. |
| 73 | — | 59 (ξ) Aquilæ | p | 4 | 2 | f | 0 | 34 | 1 | A Cl. of co. sc. st. with one pBst. M. |
| 74 | Sept. 21 | 80 (1st π) Cyg | p | 34 | 12 | f | 0 | 12 | 1 | A Cl. of co. sc. Lst. not rich 6′ dia. |
| 75 | 26 | 3 Lacertæ | p | 7 | 29 | f | 2 | 21 | 2 | A Cl. of co. sc. Lst. lE. sp nf. 16′ l. |
| 76 | 27 | 59 (1st f) Cyg | p | 4 | 1 | f | 0 | 7 | 1 | A st. 6 m. surrounded by many cst. forming a brilliant sc. Cl. the Lst. not M. but f. |
| 77 | Nov. 1 | 27 (ϑ) Cephei | f | 17 | 23 | f | 0 | 22 | 2 | A Cl. of co. sc. st. 8′ dia. C. H. 1787. |
| 78 | 26 | 15 (κ) Cassio | f | 10 | 56 | f | 1 | 8 | 2 | A Cl. of v. co. sc. Lst. take up 15 or 20′. C. H. disc. 1784. |

Notes

## Notes to ſome nebulæ and cluſters of ſtars.

I. 138. The number refers to DE LA CAILLE's ſouthern catalogue in the Cœlum Auſtrale Stelliferum.

I. 190. A ſtar of the ſixth magnitude, not contained in any catalogue. I have called it C Canum Venaticorum. It follows FL. 17. Can. Ven. 37′ 34″ in time, and is 0° 2′ more ſouth than that ſtar.

II. 566. See the note to I. 138.

638. See the note to I. 138.

697. See the note to I. 190.

703. A ſtar of the 7th magnitude, not contained in any catalogue. I called it A Ceti. Not having ſettled its place, I can only give it in a coarſe way. RA. about 0 h. 31′ 37″, PD. about 94° 22′.

III. 678. A ſtar of the 7th magnitude, not containen in any catalogue. I have called it A Bootis. It follows FL. 39 Bootis 6′ 56″ in time, and is 0° 55′ more north.

681. See the note to I. 190.

742. A ſtar of the 7th magnitude, not contained in any catalogue. I have called it B Draconis. Its place very coarſely is RA. 18 h. 47′. PD. 41°¼.

747. See Mr. WOLLASTON's general catalogue. Zone 20°.

VIII. 49. A ſtar of the 6th magnitude, not contained in any catalogue. I have called it B Geminorum. Not having ſettled its place, I can only give it in a coarſe way, RA. about 6 h. 52′ 4″. PD. about 55° 17′.

P. S. The planet Saturn has a *ſixth ſatellite* revolving round it in about 32 hours, 48 minutes. Its orbit lies exactly in the plane of the Ring, and within that of the firſt ſatellite. An account of its diſcovery with the forty-feet reflector, and a more accurate determination of its revolution and diſtance from the planet will be preſented to the Royal Society at their next Meetings. WILLIAM HERSCHEL.

## XXI. *An Attempt to explain a Difficulty in the Theory of Viſion, depending on the different Refrangibility of Light. By the Rev.* Nevil Maſkelyne, *D. D. F. R. S. and Aſtronomer Royal.*

Read June 18, 1789.

THE ideas of ſight are ſo ſtriking and beautiful, that we are apt to conſider them as perfectly diſtinct. The celebrated EULER, taking this for granted, has ſuppoſed, in the Memoirs of the Royal Academy of Sciences at Berlin for 1747, that the ſeveral humors of the human eye were contrived in ſuch a manner as to prevent the latitude of focus ariſing from the different refrangibility of light, and conſiders this as a new reaſon for admiring the ſtructure of the eye; for that a ſingle tranſparent medium, of a proper figure, would have been ſufficient to repreſent images of outward objects in an imperfect manner; but, to make the organ of ſight abſolutely complete, it was neceſſary it ſhould be compoſed of ſeveral tranſparent mediums, properly figured, and fitted together agreeable to the rules of the ſublimeſt geometry, in order to obviate the effect of the different refrangibility of light in diſturbing the diſtinctneſs of the image; and hence he concludes, that it is poſſible to diſpoſe four refracting ſurfaces in ſuch a manner as to bring all ſorts of rays to one focus, at whatever diſtance the object be placed. He then aſſumes a certain hypotheſis of refraction of the differently refran-

refrangible rays, and builds thereon an ingenious theory of an achromatic object-glaſs, compoſed of two meniſcus glaſſes with water between them, with the help of an analytical calculation, ſimple and elegant, as his uſually are.

He has not, however, demonſtrated the neceſſary exiſtence of his hypotheſis, his arguments for which are more metaphyſical than geometrical; and, as it was founded on no experiment, ſo thoſe made ſince have ſhewn its fallacy, and that it does not obtain in nature. Moreover, which is rather extraordinary, it does not account, according to his own ideas, for the very phænomenon which firſt ſuggeſted it to him, namely, the great diſtinctneſs of the human viſion, as was obſerved to me, many years ago, by the late Mr. JOHN DOLLOND, F. R. S. to whom we are ſo much obliged for the invention of the achromatic teleſcope; for the refractions at the ſeveral humors of the eye being all made one way, the colours produced by the firſt refraction will be increaſed at the two ſubſequent ones inſtead of being corrected, whether we make uſe of NEWTON's or EULER's law of refraction of the differently refrangible rays.

Thus EULER produced an hypothetical principle, neither fit for rendering a teleſcope achromatic, nor to account for the diſtinctneſs of the human viſion; and the difficulty of reconciling that diſtinctneſs with the principle of the different refrangibility of light diſcovered by Sir ISAAC NEWTON remains in its full force.

In order to go to the bottom of this difficulty, as the beſt probable means of obviating it, I have calculated the refractions of the mean, moſt, and leaſt refrangible rays at the ſeveral humors of the eye, and thence inferred the diffuſion of the rays, proceeding from a point in an object, at their falling upon

upon the retina, and the external angle which ſuch coloured image of a point upon the retina correſponds to.

I took the dimenſions of the eye from M. PETIT, as related by Dr. JURIN; and, the ſpecific gravities of the aqueous and vitreous humors having been found to be nearly the ſame with that of water, and the refraction of the vitreous humor of an ox's eye having been found by Mr. HAWKSBEE to be the ſame as that of water, and the ratio of refraction out of air into the cryſtalline humor of an ox's eye having been found by the ſame accurate experimenter to be as 1 to ,68327, I took the refraction of the mean refrangible rays out of air into the aqueous or vitreous humor, the ſame as into water, as 1 to ,74853, or 1,33595 to 1; and out of air into the cryſtalline humor as 1 to ,68327, or 1,46355 to 1. Hence I find, according to Sir ISAAC NEWTON's two theorems, related at Part II. of Book I. of Optics, p. 113. that the ratio of refraction of the moſt, mean, and leaſt refrangible rays at the cornea ſhould be as 1 to ,74512, ,74853 and ,75197; at the foreſurface of the cryſtalline as 1 to ,91173, ,91282, and ,91392; and at the hinder ſurface of the cryſtalline as 1 to 1,09681, 1,09550, and 1,09420.

Now, taking with Dr. JURIN 15 inches for the diſtance at which the generality of eyes in their mean ſtate ſee with moſt diſtinctneſs, I find the rays from a point of an object ſo ſituate will be collected into three ſeveral foci, *viz.* the moſt, mean, and leaſt refrangible rays at the reſpective diſtances behind the cryſtalline ,5930, ,6034, and ,6141 of an inch, the focus of the moſt refrangible rays being ,0211 inch ſhort of the focus of the leaſt refrangible ones.

Moreover, aſſuming the diameter of the pencil of rays at the cornea, proceeding from the object at 15 inches diſtance,

to be $\frac{1}{5}$th of an inch in a ſtrong light, which is a large allowance for it, the ſemi-angle of the pencil of mean refrangible rays at their concourſe upon the retina will be 7° 12′, whoſe tangent to the radius unity, or ,1264 multiplied into ,0211 inch, the interval of the foci of the extreme refrangible rays, gives ,002667 inch for the diffuſion of the different coloured rays, or the diameter of the indiſtinct circle upon the retina. Now, I find, that the diameter of the image of an object upon the retina is to the object as ,6055 inch to the diſtance of the object from the center of curvature of the cornea; or the ſize of the image is the ſame as would be formed by a very thin convex lens, whoſe focal diſtance is ,6055 inch, and conſequently a line in an object which ſubtends an angle of 1′ at the center of the cornea will be repreſented on the retina by a line of $\frac{1}{5678}$th inch. Hence the diameter of the indiſtinct circle on the retina before found, ,002667 will anſwer to an external angle of ,002667 × 5678′ = 15′ 8″, or every point in an object ſhould appear to ſubtend an angle of about 15′, on account of the different refrangibility of the rays of light.

I ſhall now endeavour to ſhew that this angle of ocular aberration is compatible with the diſtinctneſs of our viſion. This aberration is of the ſame kind as that which we experience in the common refracting teleſcope. Now, by computation from the tabular apertures and magnifying powers of ſuch teleſcopes, it is certain that they admit of an angular indiſtinctneſs at the eye of no leſs than 57′; therefore the ocular aberration is near four times leſs than in a common refracting teleſcope, and conſequently the real indiſtinctneſs, being as the ſquare of the angular aberration, will be 14 or 15 times leſs in the eye than in a common refracting teleſcope, which may be eaſily allowed to be imperceptible.

Moreover,

Moreover, Sir ISAAC NEWTON has obſerved, with reſpect to the like difficulty of accounting for the diſtinctneſs with which refracting teleſcopes repreſent objects, that the erring rays are not ſcattered uniformly over the circle of diſſipation in the focus of the object-glaſs, but collected infinitely more denſely in the center than in any other part of the circle, and in the way from the center to the circumference grow continually rarer and rarer, ſo as at the circumference to become infinitely rare; and by reaſon of their rarity are not ſtrong enough to be viſible, unleſs in the center and very near it.

He farther obſerves, that the moſt luminous of the priſmatic colours are the yellow and orange, which affect the ſenſe more ſtrongly than all the reſt together; and next to theſe in ſtrength are the red and green; and that the blue, indigo, and violet, compared with theſe, are much darker and fainter, and compared with the other ſtronger colours, little to be regarded; and that therefore the images of the objects are to be placed not in the focus of the mean refrangible rays, which are in the confine of green and blue, but in the middle of the orange and yellow, there where the colour is moſt luminous, that which is in the brighteſt yellow, that yellow which inclines more to orange than to green.

From all theſe conſiderations, and by an elaborate calculation, he infers, that though the whole breadth of the image of a lucid point be $\frac{1}{178}$th of the diameter of the aperture of the object-glaſs, yet the ſenſible image of the ſame is ſcarce broader than a circle whoſe diameter is $\frac{1}{2\,178}$th part of the diameter of the aperture of the object-glaſs of a good teleſcope; and hence he accounts for the apparent diameters of the fixed ſtars as obſerved with teleſcopes by aſtronomers, although in reality they are but points.

The

The like reasoning is applicable to the circle of dissipation on the retina of the human eye; and therefore we may lessen the angular aberration, before computed at 15′, in the ratio of 250 to 55, which will reduce it to 3′ 18″.

This reduced angle of aberration may perhaps be double the apparent diameter of the brightest fixed stars to an eye disposed for seeing most distinctly by parallel rays; or, if short-sighted, assisted by a proper concave lens; which may be thought a sufficient approximation in an explication grounded on a dissipation of rays, to which a precise limit cannot be assigned, on account of the continual increase of density from the circumference to the center. Certainly some such angle of aberration is necessary to account for the stars appearing under any sensible angle to such an eye; and if we were, without reason, to suppose the images on the retina to be perfect, we should be put to a much greater difficulty to account for the fixed stars appearing otherwise than as points, than we have now been to account for the actual distinctness of our sight.

The less apparent diameter of the smaller fixed stars agrees also with this theory; for the less luminous the circle of dissipation is, the nearer we must look towards its center to find rays sufficiently dense to move the sense. From Sir Isaac Newton's geometrical account of the relative density of the rays in the circle of dissipation, given in his system of the world, it may be inferred, that the apparent diameters of the fixed stars, as depending on this cause, are nearly as their whole quantity of light.

In farther elucidation of this subject let me add my own experiment. When I look at the brighter fixed stars, at considerable elevations, through a concave glass fitted, as I am short-sighted, to shew them with most distinctness, they appear

to me without ſcintillation, and as a ſmall round circle of fire of a ſenſible magnitude. If I look at them without the concave glaſs, or with one not ſuited to my eye, they appear to caſt out rays of a determinate figure, not exactly the ſame in both eyes, ſomewhat like branches of trees (which doubtleſs ariſe from ſomething in the conſtruction of the eye) and to ſcintillate a little, if the air be not very clear. To ſee day objects with moſt diſtinctneſs, I require a leſs concave lens by one degree than for ſeeing the ſtars beſt by night, the cauſe of which ſeems to be, that the bottom of the eye being illuminated by the day objects, and thereby rendered a light ground, obſcures the fainter colours blue indigo and violet in the circle of diſſipation, and therefore the beſt image of the object will be found in the focus of the bright yellow rays, and not in that of the mean refrangible ones, or the dark green, agreeable to NEWTON's remark, and conſequently nearer the retina of a ſhort-ſighted perſon; but the parts of the retina ſurrounding the circle of diſſipation of a ſtar being in the dark, the fainter colours, blue, indigo, and violet, will have ſome ſhare in forming the image, and conſequently the focus will be ſhorter.

The apparent diameter of the ſtars here accounted for is different from that explained by Dr. JURIN, in his Eſſay on diſtinct and indiſtinct viſion, ariſing from the natural conſtitution of the generality of eyes to ſee objects moſt diſtinct at moderate diſtances, and few being capable of altering their conformation enough to ſee diſtant objects, and among them the celeſtial ones, with equal diſtinctneſs. But the cauſe of error, which I have pointed out, will affect all eyes, even thoſe which are adapted to diſtant objects.

If this attempt to ſhew the compatibility of the actual diſtinctneſs of our ſight with the different refrangibility of light

light ſhall be admitted as juſt and convincing, we ſhall have freſh reaſon to admire the wiſdom of the Creator in ſo adapting the aperture of the pupil and the different refrangibility of light to each other, as to render the picture of objects upon the retina relatively, though not abſolutely, perfect, and fitted for every uſeful purpoſe; "where," to borrow the words of our religious and oratorical philoſopher DERHAM, "all the "glories of the heavens and earth are brought and exquiſitely "pictured."

Nor does it appear, that any material advantage would have been obtained, if the image of objects on the retina had been made abſolutely perfect, unleſs the acuteneſs of the optic nerve ſhould have been increaſed at the ſame time; as the *minimum viſibile* depends no leſs on that circumſtance than the other. But that the ſenſibility of the optic nerve could not have been much increaſed beyond what it is, without great inconvenience to us, may be eaſily conceived, if we only conſider the forcible impreſſion made on our eyes by a bright ſky, or even the day objects illuminated by a ſtrong ſun. Hence we may conclude, that ſuch an alteration would have rendered our ſight painful inſtead of pleaſant, and noxious inſtead of uſeful. We might indeed have been enabled to ſee more in the ſtarry heavens with the naked eye, but it muſt have been at the expence of our daily labours and occupations, the immediate and neceſſary employment of man.

I ſhall only mention farther, and obviate an objection to the diffuſion of the rays upon the retina by the different refrangibility of light. It may be ſaid, that the ocular aberration, being a ſeparate cauſe from any effect of the teleſcope, ſhould ſubſiſt equally when we obſerve a ſtar through a teleſcope as when we look at it with the naked eye; and that therefore the

fixed ſtars could not appear ſo ſmall as they have been found to do through the beſt teleſcopes, and particularly by Dr. HERSCHEL with his excellent ones. To this I anſwer, that the ocular aberration, which is proportional to the diameter of the pupil when we uſe the naked eye, is proportional to the diameter of the pencil of rays at the eye when we look through a teleſcope, which being many times leſs than that of the pupil itſelf, the ocular aberration will be diminiſhed in proportion, and become inſenſible.

XXII. *Experiments and Observations on Electricity.* *By Mr.* William Nicholſon; *communicated by Sir* Joſeph Banks, *Bart. P. R. S.*

Read June 25, 1789.

SECT. I. *On the Excitation of Electricity.*

1. A GLASS cylinder was mounted, and a cuſhion applied with a ſilk flap, proceeding from the edge of the cuſhion over its ſurface, and thence half round the cylinder. The cylinder was then excited by applying an amalgamed leather in the uſual manner. The electricity was received by a conductor, and paſſed off in ſparks to LANE's electrometer. By the frequency of theſe ſparks, or by the number of turns required to cauſe ſpontaneous exploſion of a jar, the ſtrength of the excitation was aſcertained.

2. The cuſhion was withdrawn about one inch from the cylinder, and the excitation performed by the ſilk only. A ſtream of fire was ſeen between the cuſhion and the ſilk; and much fewer ſparks paſſed between the balls of the electrometer.

3. A roll of dry ſilk was interpoſed, to prevent the ſtream from paſſing between the cuſhion and the ſilk. Very few ſparks then appeared at the electrometer.

4. A metallic rod, not inſulated, was then interpoſed, inſtead of the roll of ſilk, ſo as not to touch any part of the apparatus.

apparatus. A denſe ſtream of electricity appeared between the rod and the ſilk, and the conductor gave very many ſparks.

5. The knob of a jar being ſubſtituted in the place of the metallic rod, it became charged negatively.

6. The ſilk alone, with a piece of tin-foil applied behind it, afforded much electricity, though leſs than when the cuſhion was applied with a light preſſure. The hand, being applied to the ſilk as a cuſhion, produced a degree of excitation ſeldom equalled by any other cuſhion.

7. The edge of the hand anſwered as well as the palm.

8. When the excitation by a cuſhion was weak, a line of light appeared at the anterior part of the cuſhion, and the ſilk was ſtrongly diſpoſed to receive electricity from any uninſulated conductor. Theſe appearances did not obtain when the excitation was by any means made very ſtrong.

9. A thick ſilk, or two or more folds of ſilk, excited worſe than a ſingle very thin flap. I uſe the ſilk which the milleners call Perſian.

10. When the ſilk was ſeparated from the cylinder, ſparks paſſed between them; the ſilk was found to be in a weak negative, and the cylinder in a poſitive ſtate.

The foregoing experiments ſhew that the office of the ſilk is not merely to prevent the return of electricity from the cylinder to the cuſhion, but that it is the chief agent in the excitation; while the cuſhion ſerves only to ſupply the electricity, and perhaps increaſe the preſſure at the entering part. There likewiſe ſeems to be little reaſon to doubt but that the diſpoſition of the electricity to eſcape from the ſurface of the cylinder is not prevented by the interpoſition of the ſilk, but by a compenſation, after the manner of a charge; the ſilk being then as ſtrongly negative as the cylinder is poſitive: and, laſtly, that the line of light between

between the ſilk and cuſhion in weak excitations does not conſiſt of returning electricity, but of electricity which paſſes to the cylinder, in conſequence of its not having been ſufficiently ſupplied, during its contact with the rubbing ſurface.

11. When the excitation was very ſtrong in a cylinder newly mounted, flaſhes of light were ſeen to fly acroſs its inſide, from the receiving ſurface to the ſurface in contact with the cuſhion, as indicated by the bruſh figure. Theſe made the cylinder ring as if ſtruck with a bundle of ſmall twigs. They ſeem to have ariſen from part of the electricity of the cylinder taking the form of a charge. This appearance was obſerved in a nine-inch and a twelve-inch cylinder, and the property went off in a few weeks. Whence it appears to have been chiefly occaſioned by the rarity of the internal air produced by handling, and probably reſtored by gradual leaking of the cement.

12. With a view to determine what happens in the inſide of the cylinder, recourſe was had to a plate machine. One cuſhion was applied with its ſilken flap. The plate was nine inches in diameter and two-tenths of an inch thick. During the excitation, the ſurface oppoſite the cuſhion ſtrongly attracted electricity, which it gave out when it arrived oppoſite the extremity of the flap. So that a continual ſtream of electricity paſſed through an inſulated metallic bow terminating in balls, which were oppoſed, the one to the ſurface oppoſite the extremity of the ſilk, and the other oppoſite the cuſhion; the former ball ſhewing poſitive, and the latter negative ſigns. The knobs of two jars being ſubſtituted in the place of theſe balls, the jar, applied to the ſurface oppoſed to the cuſhion, was charged negatively, and the other poſitively. This diſpoſition of the back ſurface ſeemed, by a few trials, to be weaker the

ſtronger the action of the cuſhion, as judged by the electricity on the cuſhion ſide.

Hence it follows, that the internal ſurface of a cylinder is ſo far from being diſpoſed to give out electricity during the friction by which the external ſurface acquires it, that it even greedily attracts it.

13. A plate of glaſs was applied to the revolving plate, and thruſt under the cuſhion in ſuch a manner as to ſupply the place of the ſilk flap. It rendered the electricity ſtronger, and appears to be an improvement of the plate machine; to be admitted if there were not eſſential objections againſt the machine itſelf.

14. Two cuſhions were then applied on the oppoſite ſurfaces with their ſilk flaps, ſo as to claſp the plate between them. The electricity was received from both by applying the finger and thumb to the oppoſite ſurfaces of the plate. When the finger was advanced a little towards its correſpondent cuſhion, ſo that its diſtance was leſs than between the thumb and its cuſhion, the finger received ſtrong electricity, and the thumb none; and, contrariwiſe, if the thumb were advanced beyond the finger, it received all the electricity, and none paſſed to the finger. This electricity was not ſtronger than was produced by the good action of one cuſhion applied ſingly.

15. The cuſhion in experiment 12. gave moſt electricity when the back ſurface was ſupplied, provided that ſurface was ſuffered to retain its electricity till the rubbed ſurface had given out its electricity.

From the two laſt paragraphs it appears, that no advantage is gained by rubbing both ſurfaces; but that a well managed friction on one ſurface will accumulate as much electricity as the preſent methods of excitation ſeem capable of collecting; but

but that when the excitation is weak, on account of the electric matter not passing with sufficient facility to the rubbed surface, the friction enables the opposite surface to attract or receive it, and if it be supplied, both surfaces will pass off in the positive state; and either surface will give out more electricity than is really induced upon it, because the electricity of the opposite surface forms a charge. It may be necessary to observe, that I am speaking of the facts or effects produced by friction; but how the rubbing surfaces act upon each other to produce them, whether by attraction, or otherwise, I do not here enquire.

It will hereafter be seen, that plate machines do not collect more electricity than cylinders (in the hands of the electrical operators of this metropolis) do with half the rubbed surface; which is a corroboration of the inference here made.

16. When a cylinder is weakly excited, the appearances mentioned (par. 8.) are more evident, the more rapid the turning. In this case, the avidity of the surface of the cylinder beneath the silk is partly supplied from the edge of the silk which throws back a broad cascade of fire, sometimes to the distance of above twelve inches. From these causes it is that there is a determinate velocity of turning required to produce the maximum of intensity in the conductor. The stronger the excitation the quicker may be the velocity; but it rarely exceeds five feet of the glass to pass the cushion in a second.

17. If a piece of silk be applied to a cylinder, by drawing down the ends, so that it may touch half the circumference, and the cylinder be then turned and excited by applying the amalgamed leather, it will become very greedy of electricity during the time it passes under the silk. And if the entering surface of the glass be supplied with electricity, it will give it out at the other extremity of contact; that is to say, if insu-

lated conductors be applied at the touching ends of the silk, the one will give, and the other receive, electricity until the intensities of their opposite states are as high as the power of the apparatus can bring them; and these states will be instantly reversed by turning the cylinder in the opposite direction.

As this discovery promises to be of the greatest use in electrical experiments, because it affords the means of producing either the plus or minus states in one and the same conductor, and of instantly repeating experiments with either power, and without any change of position or adjustment of the apparatus, it evidently deserved the most minute examination.

18. There was little hope (par. 6.) that cushions could be dispensed with. They were therefore added; and it was then seen, that the electrified conductors were supplied by the difference between the action of the cushion which had the advantage of the silk and that which had not; so that the naked face of the cylinder was always in a strong electric state. Methods were used for taking off the pressure of the receiving cushion; but the extremity of the silk, by the construction, not being immediately under that cushion, gave out large flashes of electricity with the power that was used. Neither did it appear practicable to present a row of points or other apparatus to intercept the electricity which flew round the cylinder; because such an addition would have materially diminished the intensity of the conductor, which in the usual way was such as to flash into the air from rounded extremities of four inches diameter, and made an inch and half ball become luminous and blow like a point. But the greatest inconvenience was, that the two states with the backward and forward turn were seldom equal; because the disposition of the amal-

gam

gam on the ſilk, produced by applying the leather to the cylinder in one direction of turning, was the reverſe of what muſt take place when the contrary operation was performed.

Notwithſtanding all this, as the intenſity with the two cuſhions was ſuch as moſt operators would have called ſtrong, the method may be of uſe, and I ſtill mean to make more experiments when I get poſſeſſion of a very large machine which is now in hand.

19. The more immediate advantage of this diſcovery is, that it ſuggeſted the idea of two fixed cuſhions with a moveable ſilk flap and rubber. Upon this principle, which is ſo ſimple and obvious, that it is wonderful it ſhould have been ſo long overlooked, I have conſtructed a machine with one conductor, in which the two oppoſite and equal ſtates are produced by the ſimple proceſs of looſening the leather rubber, and letting it paſs round with the cylinder (to which it adheres) until it arrives at the oppoſite ſide, where it is again faſtened. A wiſh to avoid prolixity prevents my deſcribing the mechaniſm by which it is let go, and faſtened in an inſtant, at the ſame time that the cuſhion is made either to preſs or is withdrawn, as occaſion requires.

20. Although the foregoing ſeries of experiments naturally lead us to conſider the ſilk as the chief agent in excitation; yet as this buſineſs was originally performed by a cuſhion only, it becomes an object of enquiry to determine what happens in this caſe.

21. The great BECCARIA * inferred, that in a ſimple cuſhion, the line of fire, which is ſeen at the extremity of contact from which the ſurface of the glaſs recedes, conſiſts of returning electricity; and Dr. NOOTH grounded his happy

* Philoſophical Tranſactions, Vol. LVI. p. 117.

invention of the ſilk flap upon the ſame ſuppoſition. The former aſſerts, that the lines of light both at the entering and departing parts of the ſurface are abſolutely ſimilar; and thence infers, that the cuſhion receives on the one ſide, as it certainly does on the other. I find, however, that the fact is directly contrary to this aſſertion; and that the oppoſite inference ought to be made, as far as this indication can be reckoned concluſive: for the entering ſurface exhibits many luminous perpendiculars to the cuſhion, and the departing ſurface exhibits a neat uniform line of light. This circumſtance, together with the conſideration that the line of light behind the ſilk in par. 8. could not conſiſt of returning electricity, ſhewed the neceſſity of farther examination. I therefore applied the edge of the hand as a rubber, and by occaſionally bringing forward the palm, I varied the quantity of electricity which paſſed near the departing ſurface. When this was the greateſt, the ſparks at the electrometer were the moſt numerous. But, as the experiment was liable to the objection that the rubbing ſurface was variable, I paſted a piece of leather upon a thin flat piece of wood, then amalgamed its whole ſurface, and cut its extremity off in a neat right line cloſe to the wood. This being applied by the conſtant action of a ſpring againſt the cylinder, produced a weak excitation, and the line where the contact of the cylinder and leather ceaſed (as abruptly as poſſible) exhibited a very narrow fringe of light. Another piece of wood was prepared of the ſame width as the rubber, but one quarter of an inch thick, with its edges rounded, and its whole ſurface covered with tin-foil. This was laid on the back of the rubber, and was there held by a ſmall ſpring, in ſuch a manner as that it could be ſlided onward, ſo as occaſionally to project beyond the rubber, and cover the departing and excited ſurface

of

of the cylinder, without touching it. The ſparks at the electrometer were four times as numerous when this metallic piece was thus projected; but no electricity was obſerved to paſs between it and the cylinder. The metallic piece was then held in the hand to regulate its diſtance from the glaſs; and it was found, that the ſparks at the electrometer increaſed in number as it was brought nearer, until light appeared between the metal and the cylinder, at which time they became fewer the nearer it was brought, and at laſt ceaſed when it was in contact.

The following concluſions appear to be deducible from theſe experiments. 1. The line of light on a cylinder departing from a ſimple cuſhion conſiſts of returning electricity; 2. the projecting part of the cuſhion compenſates the electricity upon the cylinder, and by diminiſhing its intenſity prevents its ſtriking back in ſuch large quantities as it would otherwiſe do; 3. that if there were no ſuch compenſation, very little of the excited electricity would be carried off; and, 4. that the compenſation is diminiſhed, or the intenſity increaſed, in an higher ratio than that of the diſtance of the compenſating ſubſtance; becauſe if it were not, the electricity which has been carried off from an indefinitely ſmall diſtance, would never fly back from a greater diſtance and form the edge of light.

22. I hope the conſiderable intenſity I ſhall ſpeak of will be an apology for deſcribing the manner in which I produce it. I wiſh the theory of this very obſcure proceſs were better known; but no conjecture of mine is worth mentioning. The method is as follows:

Clean the cylinder, and wipe the ſilk.

Greaſe the cylinder by turning it againſt a greaſed leather till it is uniformly obſcured. I uſe the tallow of a candle.

Turn

Turn the cylinder till the ſilk flap has wiped off ſo much of the greaſe as to render it ſemi-tranſparent.

Put ſome amalgam on a piece of leather, and ſpread it well ſo that it may be uniformly bright. Apply this againſt the turning cylinder. The friction will immediately increaſe, and the leather muſt not be removed until it ceaſes to become greater.

Remove the leather, and the action of the machine will be very ſtrong.

My rubber, as before obſerved, conſiſts of the ſilk flap paſted to a leather, and the cuſhion is preſſed againſt the ſilk by a ſlender ſpiral ſpring in the middle of its back. The cuſhion is looſely retained in a groove, and reſts againſt the ſpring only, in ſuch a manner that by a ſort of libration upon it as a fulcrum, it adapts itſelf to all the irregularities of the cylinder, and never fails to touch in its whole length. There is no adjuſtment to vary the preſſure, becauſe the preſſure cannot be too ſmall when the excitation is properly made. Indeed, the actual withdrawing of the cuſhion to the diſtance of one-tenth of an inch from the ſilk, as in par. 2. will not materially affect a good excitation.

The amalgam is that of Dr. HIGGINS, compoſed of zinc and mercury. If a little mercury be added to melted zinc, it renders it eaſily pulverable, and more mercury may be added to the powder to make a very ſoft amalgam. It is apt to cryſtallize by repoſe, which ſeems in ſome meaſure to be prevented by triturating it with a ſmall proportion of greaſe: and it is always of advantage to triturate it before uſing.

A very ſtrong excitation may be produced by applying the amalgamed leather to a clean cylinder with a clean ſilk. But

it ſoon goes off, and is not ſo ſtrong as the foregoing, which laſts ſeveral days.

23. To give ſome diſtinctive criterions by which other electricians may determine whether the intenſity they produce exceeds or falls ſhort of that which this method affords, I ſhall mention a few facts.

With a cylinder 7 inches diameter and cuſhion 8 inches long, three bruſhes at a time conſtantly flew out of a three-inch ball in a ſucceſſion too quick to be counted, and a ball of 1¼ inch diameter was rendered luminous, and produced a ſtrong wind like a point. A nine-inch cylinder with an eight-inch cuſhion occaſioned frequent flaſhes from the round end of a conductor 4 inches diameter: with a ball of 2¼ inches diameter the flaſhes ceaſed now and then, and it began to appear luminous: a ball of 1¼ inch diameter firſt gave the uſual flaſhes; then, by quicker turning, it became luminous with a bright ſpeck moving about on its ſurface, while a conſtant ſtream of air ruſhed from it; and, laſtly, when the intenſity was greateſt, bruſhes, of a different kind from the former, appeared. Theſe were leſs luminous, but better defined in the branches; many ſtarted out at once with a hoarſe ſound. They were reddiſh at the ſtem, ſooner divided, and were greeniſh at the point next the ball, which was braſs. A ball of $\frac{+}{10}$ inch diameter was ſurrounded by a ſteady faint light, enveloping its exterior hemiſphere, and ſometimes a flaſh ſtruck out at top. When the excitation was ſtrongeſt a few flaſhes ſtruck out ſideways. The horizontal diameter of the light was longeſt, and might meaſure one inch, the ſtem of the ball being vertical.

This laſt phænomenon is ſimilar to a natural event related by M. Loammi Baldwin *, who raiſed an electrical kite in

* Memoirs of the American Academy, Vol. I. p. 257.

July,

July, 1771, during the approach of a ſevere thunder-ſtorm, and obſerved himſelf to be ſurrounded by a rare medium of fire, which, as the cloud roſe nearer the zenith, and the kite roſe higher, continued to extend itſelf with ſome gentle faint flaſhes. Mr. BALDWIN felt no other effect than a general weakneſs in his joints and limbs, and a kind of liſtleſs feeling; all which he obſerves might poſſibly be the effect of ſurprize, though it was ſufficient to diſcourage him from perſiſting in any farther attempt at that time. He therefore drew in his kite, and retired to a ſhop till the ſtorm was over, and then went to his houſe, where he found his parents and friends much more ſurpriſed than he had been himſelf; who, after expreſſing their aſtoniſhment, informed him, that he appeared to them (during the time he was raiſing the kite) to be in the midſt of a large bright flame of fire, attended with flaſhings; and that they expected every moment to ſee him fall a ſacrifice to the flame. The ſame was obſerved by ſome of his neighbours, who lived near the place where he ſtood.

This fact is ſimilar to another obſerved by M. DE SAUSSURE on the Alps, and both are referable to my luminous ball with the ſecond kind of bruſh. The cloud muſt have been negative.

With a 12-inch cylinder, and rubber of 7¼ inches, a five-inch ball gave frequent flaſhes, upwards of 14 inches long, and ſometimes a ſix-inch ball would flaſh. I do not mention the long ſpark, becauſe I was not provided with a favourable apparatus for the two larger cylinders. The 7-inch cylinder affords a ſpark of 10¼ inches at beſt. The 9-inch cylinder, not having its conductor inſulated on a ſupport ſufficiently high, afforded flaſhes to the table which was 14 inches diſtant. And the 12-inch cylinder, being mounted only as a model or trial for conſtructing a larger apparatus, is defective in ſeveral

reſpects

reſpects which I have not thought fit to alter. When the five-inch ball gives flaſhes, the cylinder is enveloped on all ſides with fire which ruſhes from the receiving part of the conductor. I never uſe points, but in a ſimple machine bring the conductor almoſt in contact with the cylinder. In this apparatus that cuſhion to which the rubber is not applied ſerves that purpoſe.

24. Theſe marks exhibit the intenſity as deduced from ſimple electrifying. I will now mention the rate of charging, which was nearly the ſame in all the three cylinders.

A large jar of 350 ſquare inches, or near 2½ ſquare feet, with an uncoated varniſhed rim, of more than four inches in height, was made to explode ſpontaneouſly over the rim. The jar, when broken, proved to be 0.082 inches thick on an average; and the number of ſquare feet of the ſurface of the cylinder which was rubbed, to produce the charge of one foot, was, when leaſt, 18.03, and when moſt, with good excitation, 19.34. The great machine at Harlem charges * a ſingle jar of one foot ſquare by the friction of 66.6 ſquare feet, and charges its battery of 225 ſquare feet at the rate of 94.8 ſquare feet rubbed for each foot. The intenſity of electricity on the ſurface of the glaſs is therefore conſiderably leſs than one-fourth of that here ſpoken of; but if we take the moſt favourable number 66.6 at the commencement of turning, and halve it on account of the unavoidable imperfection of a plate machine (as ſhewn in par. 14.), it will be found, that the management applied to that machine would cauſe a cylinder to charge one ſquare foot by the friction of 33⅓ ſquare feet. It muſt be obſerved, however, that M. VAN MARUM's own machine, con-

* To explode from the central wire, which, from ſome trials, I find to require leſs force than from coating to coating at equal diſtances.

ſiſting of two plates, 33 inches diameter, has only half the intenſity, though he reckons it a very good one. This machine is about equal in abſolute power to my 9-inch cylinder, with its ſhort rubber; but it is near thirty times as dear in price. In all theſe deductions I omit the computations, for the ſake of brevity, and becauſe they are eaſily made. The *data* are found in the deſcription of the Teylerian machine, and its continuation publiſhed at Harlem in the years 1785 and 1787.

I ſhall here take the liberty of obſerving, that the action of the cylinder, by a ſimple cuſhion or the hand, which excited the aſtoniſhment of all Europe, in the memory of our co-temporaries, was firſt improved by the addition of a leathern flap; then by moiſtening the rubber; afterwards by applying the amalgam; and, laſtly, by the addition of a ſilk flap. Now, I find, by experiment, that we at preſent obtain upwards of forty times the intenſity which the bare hand produces; and conſequently that, ſince eighteen times our preſent intenſity will equal the utmoſt we can now condenſe on ſtrong glaſs even in the form of a charge; we have a leſs ſtep to take before we arrive at that amazing power, than our immediate predeceſſors have already made.

My 9-inch cylinder, when broken, proved to be $\frac{1}{11}$ of an inch thick.

## SECT. II. *Upon the luminous Appearances of Electricity and the Action of Points.*

25. Some of the luminous appearances, with balls in the poſitive ſtate, have been ſlightly noticed as criterions of intenſity. I ſhall here add, that the eſcape of negative electricity from a ball is attended with the appearance of ſtrait ſharp ſparks with a

hoarſe or chirping noiſe. When the ball was leſs than two inches in diameter, it was uſually covered with ſhort flames of this kind, which were very numerous.

26. When two equal balls were preſented to each other, and one of them was rendered ſtrongly poſitive, while the other remained in connection with the earth, the poſitive bruſh or ramified ſpark was ſeen to paſs from the electrified ball: when the other ball was electrified negatively, and the ball, which before had been poſitive, was connected with the ground, the electricity (paſſing the ſame way according to FRANKLIN) exhibited the negative flame, or denſe ſtraight and more luminous ſpark, from the negative ball; and when the one ball was electrified *plus* and the other *minus*, the ſigns of both electricities appeared. If the interval was not too great, the long zig-zag ſpark of the *plus* ball ſtruck to the ſtrait flame of the *minus* ball, uſually at the diſtance of about one-third of the length of the latter from its point, rendering the other two-thirds very bright. Sometimes, however, the poſitive ſpark ſtruck the ball at a diſtance from the negative flame. Theſe effects are repreſented in Plate IV. fig. 1, 2 and 3.

27. Two conductors of three-quarters of an inch diameter, with ſpherical ends of the ſame diameter, were laid parallel to each other, at the diſtance of about two inches, in ſuch a manner as that the ends pointed in oppoſite directions, and were ſix or eight inches aſunder. Theſe, which may be diſtinguiſhed by the letters P and M, were ſucceſſively electrified as the balls were in the laſt paragraph. When one conductor P was poſitive, fig. 5. it exhibited the ſpark of that electricity at its extremity, and ſtruck the ſide of the other conductor M. When the laſt-mentioned conductor M was electrified negatively, fig. 4. the former being in its turn connected with the earth,

the ſparks ceaſed to ſtrike as before, and the extremity of the electrified conductor M exhibited negative ſigns, and ſtruck the ſide of the other conductor. And when one conductor was electrified *plus* and the other *minus*, fig. 6. both ſigns appeared at the ſame time, and continual ſtreams of electricity paſſed between the extremities of each conductor to the ſide of the other conductor oppoſed to it. In each of theſe three caſes, the current of electricity, on the hypotheſis of a ſingle fluid, paſſed the ſame way.

28. In drawing the long ſpark from a ball of four inches diameter, I found it of ſome conſequence that the ſtem ſhould not be too ſhort, becauſe the vicinity of the large prime conductor altered the diſpoſition of the electricity to eſcape; I therefore made a ſet of experiments, the reſult of which ſhewed, that the diſpoſition of balls to receive or emit electricity is greateſt when they ſtand remote from other ſurfaces in the ſame ſtate; and that between this greateſt diſpoſition in any ball, whatever may be its diameter, every poſſible leſs degree may be obtained by withdrawing the ball towards the broader or leſs convex ſurface out of which its ſtem projects, until at length the ball, being wholly depreſſed beneath that ſurface, loſes the diſpoſition entirely. From theſe experiments it follows, that a variety of balls is unneceſſary in electricity; becauſe any ſmall ball, if near the prime conductor, will be equivalent to a larger ball whoſe ſtem is longer.

29. From comparing ſome experiments, made by myſelf many years ago, with the preſent ſet, I conſidered a point as a ball of an indefinitely ſmall diameter, and conſtructed an inſtrument conſiſting of a braſs ball of ſix inches diameter, through the axis of which a ſtem, carrying a fine point, was ſcrewed. When this ſtem is fixed in the prime conductor, if

the

the ball be moved on its axis in either direction, it cauſes the fine point either to protrude through a ſmall hole in its external ſurface, or to withdraw itſelf; becauſe by this means the ball runs along the ſtem. The diſpoſition of the point to tranſmit electricity may thus be made equal to that of any ball whatever, from the minuteſt ſize to the diameter of ſix inches. See fig. 7. let. A.

30. The action of pointed bodies has been a ſubject of diſcuſſion ever ſince it was firſt diſcovered, and is not yet well explained. To thoſe who aſcribe this effect to the figure of electric atmoſpheres, and their diſpoſition to fly off, it may be anſwered, that they ought firſt to prove their exiſtence, and then ſhew why the cauſe which accumulated them does not prevent their eſcape; not to mention the difficulty of explaining the nature of negative atmoſpheres. If theſe be ſuppoſed to conſiſt of electrified air, it will not be eaſy to ſhew why a current of air paſſing near a prime conductor does not deſtroy its effects. The opinion, ſupported by the celebrated VOLTA and others, that a point is the coating to an infinitely ſmall plate of air, does not appear better founded: for ſuch a plate muſt be broken through at a greater diſtance only becauſe higher charged; whence it would follow, that points ſhould not act but at high intenſities. I muſt likewiſe take notice, as a proof that the charge has little to do here, that if a ball be preſented to the prime conductor, at the ſame time that a point proceeds from the oppoſite ſide of the ball, the electricity will paſs by the point, though it is obliged to go round the ball for that purpoſe; but it can hardly be doubted, that whatever charge obtains in this caſe is on the ſurface of the ball next the conductor, and not on the remote ſide to which the electricity directs its courſe.

31. ACHARD's

31. ACHARD's experiments with a number of pointed cones, ſcrewed in a plate of metal, and likewiſe the pointed apparatus deſcribed (par. 29) ſhew that the effect of points depends on the remoteneſs of their extremities from the other parts of the conductor. This leads to the following general law.

*In any electrified conductor the tranſition or eſcape of electricity will be made chiefly from that part of the ſurface which is the moſt remote from the natural ſtate.*

Thus in the apparatus of the ball and ſtem, the point having a communication with the reſt of the whole conductor, conſtantly poſſeſſes the ſame intenſity; but the influence of the ſurrounding ſurface of the ball diminiſhes its capacity. This diminution is leſs the farther the ball is withdrawn, and conſequently the point will really poſſeſs more electricity, and be more diſpoſed to give it out when it is prominent than when depreſſed. The ſame explanation ſerves for negative electricity.

32. The effect of a poſitive ſurface appears to extend farther than that of a negative: for the point acts like a ball when conſiderably more prominent if it be poſitive than it will if negative. This property was uſed by me ſome years ago for the conſtruction of an inſtrument to diſtinguiſh the two electricities *.

For the ſake of conciſeneſs I paſs over many facts which have preſented themſelves in the courſe of my experiments on the two electricities, and content myſelf with obſerving, that there is ſcarcely any experiment made with the poſitive power which will not afford a reſult worthy of notice, if repeated with the negative.

* Introduction to Natural Philoſophy, Vol. II. p. 320.

33. When

33. When we conſider that our machines can cauſe a ball of an inch and half diameter to act like a point, and that our apparatus makes a point act like a ball; if at the ſame time we remark the ſmall elevation of our conductors for lightning above the extended ſurface of the ground, and the ſmall ſize of the balls propoſed by ſome to be uſed as terminations; the diſpute, which was ſo much agitated reſpecting them, will perhaps be found to relate to a very minute circumſtance, among the many which govern the great operations of nature. It does not ſeem probable, that any conductor would act ſilently if the main courſe of the electricity of a negative cloud were to paſs through it, and many would probably receive the ſtroke from a poſitive cloud. It does not, however, follow from this, that they might not conduct it with ſafety.

## Sect. III. *Of compenſated Electricity.*

34. It is unneceſſary to inſiſt upon what is called the equilibrium of an electrical charge, becauſe Dr. Franklin has admirably explained it according to his hypotheſis. But there is another important particular, which has been almoſt entirely overlooked, namely, the uncompenſated electricity which is as eſſential to the charge as that which is in equilibrio. Whenever a jar is charged, the greateſt part of the electricity becomes latent on account of the compenſation; but there is a certain proportion which remains on the inſulated ſide, and exerts its force to prevent the electricity from returning to the outer ſurface. In moderate intenſities, this will explode, and carry the charge with it, to diſtances which are in proportion to the quantity of the charge itſelf; but in greater intenſities the diſtances greatly exceed that proportion. With glaſſes of different thickneſſes, this intenſity,

as

as meaſured by the explosive ſpark, is as the thickneſs, when the charges are equal, as Mr. CAVENDISH has determined, and I find likewiſe by experiments with thin ſubſtances; but when the thickneſſes are greater, it increaſes in a higher proportion, as is found by the exploſion which takes place between the electrophore and its plate, as well as by other experiments.

35. This uncompenſated part of the charge (which is commonly in proportion to the quantity of latent or compenſated electricity, or to the diſtance at which it exerts its action) was found to be greatly increaſed when a ſeries of jars were made to charge each other. If a jar be inſulated and made to explode by LANE's electrometer at a determinate number of turns; and another jar be then connected with its external coating ſo as to become charged by that means, the exploſion, from the outſide of the laſt to the inſide of the firſt, will take place at the electrometer (unaltered) with much fewer turns. Or if the electrometer be altered till the exploſion takes place at the original number, the diſtance will be much greater than before. Hence we ſee, that the intenſity of the uncompenſated part muſt be greater when there is a greater charge to be maintained, whether it be on one ſurface only, or on two ſurfaces ſucceſſively connected. I have not yet made the experiments neceſſary to aſcertain the law of this laſt action.

36. It is evident, that the breaking of jars is not effected by any attraction between the electricities which form the charge, but by this neceſſary ſurplus: for thicker glaſſes require much leſs electricity to produce an intenſity which breaks them than thinner do; and I found a piece of Muſcovy talc, one hundredth of an inch thick, to bear a charge conſiſting of ten times the quantity of electricity which was ſufficient to have charged an equal ſurface of common glaſs ſo as to break it.

But

But the intenſity of the very denſe charge on the talc was ſo low as to afford an exploſion of no more than about one-tenth of an inch, while that of the glaſs jar it was compared with exploded through about five inches.

The perforation of glaſs by the long ſpark, or by the ſpark through oil or cement, ſeems to depend on the very great intenſity of the electricity which has not time to diffuſe itſelf, but charges a minute part of the ſurface very high.

37. Muſcovy talc * being a very perfect non-conductor, and capable of being divided into plates of leſs thickneſs than one two-hundredth part of an inch, I made many experiments with it, which are too numerous to enter into this Paper. In conſequence of its great capacity it gives very ſtrong ſhocks. Contrary to the aſſertion of BECCARIA, I found that its laminæ are naturally in ſtrong oppoſite ſtates of electricity, and flaſh to each other when torn aſunder in the dark. A large piece being ſplit in two, the parts were found to be in oppoſite ſtates. The greateſt care was taken in theſe experiments to avoid friction, and to uſe ſuch pieces as had never been excited, nor brought near the machine.

38. The moſt plauſible objection againſt the probability of danger from the returning ſtroke of the Earl of STANHOPE is, that the quantity of electricity in an animal is too ſmall to produce any miſchievous effect. This the noble author has anſwered by remarking, that the quantity has not been ſhewn to be ſmall †. My experiments with talc ſhewing that it naturally poſſeſſes much electricity, led me to inveſtigate the quantity which a man may contain. I melted ſealing wax upon BENNET's electrometer with a burning glaſs, and found it pro-

* I am not certain whether HENLEY or BECCARIA firſt uſed this ſubſtance; but little attention was paid to it by either. † Phil. Tranſ. Vol. LXXVII. p. 143.

duced no electricity either in heating or cooling. I also placed a piece of red-hot glass upon the same instrument, and it cooled without affording electric signs. These experiments shewed, that the natural quantity of electricity is the same in these bodies, whether they be in the conducting or non-conducting state; and consequently, if it can be proved, that an electric contains a large quantity of electricity, the inference may be fairly extended to non-electrics. And it will not be disputed, upon any hypothesis, but that a non-conductor, or its coating, contains as much of what we call electricity as can be driven out of it in the act of charging. Two square inches of talc, of the thickness of 0,011 inch, were repeatedly charged and made to explode over the uncoated part, by each turn of a seven-inch cylinder. The intensity of the excitation was such, that a conductor, of three feet long, and seven inches diameter, gave a dense spark of 9 inches long at each turn. Now, in round numbers 45 such plates of talc, laid upon each other, would have formed a solid inch of matter; and from this, if fitted up as a Beccaria's battery, we could with our machine drive out electricity enough simply to charge a conductor 45 times as long (neglecting the ends); that is to say, we find that one solid inch of talc contains electricity enough to charge a conductor of 7 inches diameter, and 135 feet long, so high as to give a nine-inch spark at least, but how much more it contains we know not.

If it be here objected, that the talc does nothing more than separate the coatings, we may make use of gold leaf for our coating; which substance being (as I find by weight and measurement) no more than $\frac{1}{315000}$ of an inch thick, would increase the result near three thousand times.

Without

Without referring to the intenſe electricity of a cloud, or the bulk of a man, it may be obſerved, that ſuch a ſpark would be very painful. But to purſue our computation. The cylinder charged a ſquare foot of glaſs, of about 0.08 thick, in 15 turns ſo as to explode over a rim above four inches high. Fifteen of the pieces of talc would therefore poſſeſs as much electricity as makes the charge of a jar of one foot ſquare, and the 45 pieces or ſolid inch would contain enough to charge three ſquare feet. If we ſuppoſe the bulk of a man to be only 3 ſolid feet or 5184 ſolid inches, the natural electricity of this maſs, as deduced from the foregoing facts, will be equal to the charge of a battery of upwards of 15,000 ſquare feet.

I beg leave to obſerve, in concluding this Paper, that I have been very careful in repeating the experiments with many precautions which the experienced in this branch of natural philoſophy will perceive the neceſſity of; though, in order to keep this communication within proper limits, I have here avoided a minute deſcription of them. With the ſame view I have likewiſe forborn to ſpeak either of theory, or of a number of other experimental reſearches I have made during the courſe of this enquiry. Dates are entirely omitted from a conviction that the priority of accidental diſcovery is not worth contending for, and that no diſputes ever ariſe about that general tenor of conduct in the cultivation of ſcience, upon which the rational part of mankind ground their approbation or cenſure.

New North-ſtreet,
May 14, 1789.

P. S. Since the above was written, the *Journal de Phyſique* for April, 1789, has arrived. It contains an excellent Paper of M. VAN MARUM, giving an account of ſome very conſiderable amendments of the rubber, and of the manner of applying it to plate machines. The chief improvement conſiſts in fixing the ſilk to the poſterior part of the rubber, ſo that it covers the whole face, and has the amalgam applied upon it. I cannot, however, avoid expreſſing my ſurprize, that this improvement, which has been in common uſe in England for upwards of twelve years paſt, ſhould now be offered as a diſcovery by ſo experienced a philoſopher. With his new rubbers M. VAN MARUM excites his plates of 33 inches diameter ſo ſtrongly as to produce nearly two-thirds of the former effect of the Teylerian machine, though the rubbed ſurfaces of theſe machines are now as 691 to 2409. This power would charge the ſingle jar by the friction of 28.6 ſquare feet, or the battery by rubbing 36.2 feet, inſtead of the numbers 66.6 and 94.8, as given in par. 24. This is a vaſt acquiſition of intenſity; but ſtill little more than half that of the ſurface of a cylinder, as mentioned in the ſame paragraph. But if par. 14. be admitted to prove that plate machines gain nothing by the friction of the back ſurfaces, it will follow, that M. VAN MARUM's management, if applied to a cylinder, would do better than mine.

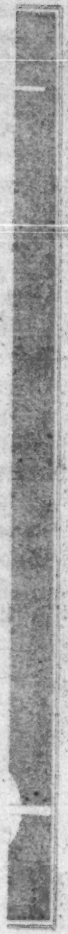

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Aspinwall Sc.

## XXIII. *Experiments on the Tranſmiſſion of the Vapour of Acids through an hot earthen Tube, and further Obſervations relating to Phlogiſton.* By the Rev. Joſeph Prieſtley, LL.D. F.R.S.

Read July 2, 1789.

IN my late experiments on the *phlogiſtication of ſpirit of nitre by heat* it appeared, that when pure air was expelled from what is called dephlogiſticated ſpirit of nitre, the remainder was left phlogiſticated. This I find abundantly confirmed by repeating the experiments in a different manner, and on a larger ſcale; and I have applied the ſame proceſs to other acids and liquors of a different kind. From theſe it will appear, that oil of vitriol and ſpirit of nitre, in their moſt dephlogiſticated ſtate, conſiſt of a proper ſaturation of the acids with phlogiſton, ſo that what we have called the *phlogiſtication* of them, ought rather to have been called their *ſuper-phlogiſtication.*

I began with treating a quantity of oil of vitriol as I had done the ſpirit of nitre, *viz.* expoſing it to heat in a glaſs tube, hermetically ſealed, and nearly exhauſted; and the reſult was ſimilar to that of the experiment with the nitrous acid, with reſpect to the expulſion of air from it, though the phlogiſtication not appearing by any change of *colour*, I did not in this method aſcertain that circumſtance. The particulars were as follows.

After the acid had been made to boil ſome time, a denſe white vapour appeared in quick motion at a diſtance above the acid,

acid, and though, on withdrawing the fire, that vapour diſappeared, it inſtantly re-appeared on renewing the heat. When the tube was cool, I opened it under water, and a quantity of air ruſhed out, though the acid had been made to boil violently while it was cloſing, ſo that there could not have been much air in the tube. This air, which muſt therefore have been generated in the tube, was a little worſe than common air, being of the ſtandard of 1.12 when the latter was 1.04. I repeated the experiment ſeveral times, and always with the ſame reſult.

That this air ſhould be worſe than common air, I cannot well explain. But in my former experiments it appeared that vitriolic acid air injures common air; and that in proportion as pure air is expelled from this acid, the remainder becomes phlogiſticated, or charged with vitriolic acid air, clearly appeared in the following experiment.

Making a quantity of oil of vitriol boil in a glaſs retort, and making the vapour paſs through a red-hot earthen tube, glazed inſide and out, and filled with pieces of broken tubes, I collected the liquor that diſtilled over, and found it to be the ſame thing with water impregnated with vitriolic acid air. The ſmell of it was exceedingly pungent, and it was evident, that more of this air had eſcaped than could be retained by that quantity of water. The oil of vitriol uſed in this proceſs was 1 oz. 9 dw. 18 gr. and the liquor collected was 6 dw. 12 gr. When I collected the air that was produced in this manner, which I did not do at this time, it appeared to be very pure, about the ſtandard of 0.3 with two equal meaſures of nitrous air.

At another time, expending 1 oz. 11 dw. 18 gr. of oil of vitriol, of the ſpecific gravity of 1856 (that of water being 1000),

1000), I collected 19 dw. 6 gr. of the volatile acid, of the ſpecific gravity of 1340, and 130 oz. meaſures of dephlogiſticated air of the pureſt kind, *viz.* of the ſtandard of 0.15.

It is eaſy in this manner to collect a great quantity of dephlogiſticated air; but the principal objection to the proceſs is, that after uſing a few times, the earthen tubes become tender, and too eaſily break, eſpecially in heating or cooling. It is alſo difficult to lute the retort containing the acid and the earthen tube. The air produced in this manner is filled with the denſeſt white cloud imaginable.

Going through the ſame proceſs with ſpirit of nitre, the reſult was in all reſpects ſimilar, but much more ſtriking, the production of both dephlogiſticated air and phlogiſticated acid vapour being prodigiouſly quicker, and more abundant. Expending 5 oz. 8 dw. 6 gr. of ſpirit of nitre, I collected 600 oz. meaſures of very pure dephlogiſticated air, being of the ſtandard of 0.2. I alſo collected 1 oz. 7 dw. 14 gr. of a greeniſh acid of nitre, which emitted copious red fumes. All the apparatus beyond the hot tube was filled with the denſeſt red vapour, and the water of the trough in which the air was received was ſo much impregnated with it, that the ſmell was very ſtrong; and it ſpontaneouſly yielded nitrous air ſeveral days, juſt as water does when impregnated with nitrous vapour. Perceiving the emiſſion of air from the water, after it had ſtood ſome time, I filled a jar containing 30 oz. meaſures with it, and without any heat it yielded two oz. meaſures of the ſtrongeſt nitrous air.

Taking the ſpecific gravity of the acid before and after this diſtillation, the former was to the latter as 1471 to 1182. When the weight of the air produced in this experiment, and that of the liquor diſtilled, is compared with that of the acid

before diſtillation, it will appear, that there muſt have been a great loſs of acid vapour, which was either retained in the water of the trough, or eſcaped through it.

I do not ſee that theſe experiments can be explained, but on the ſuppoſition that the moſt dephlogiſticated oil of vitriol and ſpirit of nitre are, in a proper ſenſe, ſaturated with phlogiſton; and that when part of the acidifying principle is expelled in the form of the air, the remainder is ſuperſaturated with it.

To try whether the acid, thus ſuperſaturated with phlogiſton, was convertible into pure air by this proceſs, I heated the liquor collected after the diſtillation of the oil of vitriol, that is, water impregnated with vitriolic acid air, and made the vapour paſs through the hot tube, but no air came from it; and when collected a ſecond time, it was not at all different from what it had been before. The ſpecific gravity was alſo the ſame.

It is evident, however, though this proceſs does not ſhew it, that the volatile vitriolic acid contains the proper element of dephlogiſticated air; ſince by melting iron in vitriolic acid air, a quantity of fixed air (which is compoſed of inflammable and dephlogiſticated air) is produced. Melting iron in 9 oz. meaſures of vitriolic acid air, it was reduced to 0.3 oz. meaſures, and of this 0.17 oz. meaſures was fixed air. I repeated the experiment with the ſame reſult, and putting the reſiduums together found the air to be inflammable.

But the reſult was ſomething different when I ſent through the hot tube the liquor that I had collected in the proceſs with ſpirit of nitre. No air, however, was produced at the firſt, nothing appearing beſides a *red vapour* that was wholely abſorbed by water, or eſcaped through it into the atmoſphere; but towards the end of the proceſs I collected 10 oz. meaſures of dephlo-

dephlogiſticated air. The quantity of the liquor expended was about 2 oz. meaſures. It may, however, be preſumed, that this ſmall quantity of air came from ſome of the acid which eſcaped the action of the fire in the former proceſs. Indeed its coming at the laſt only may be conſidered as a proof of this, as all the more volatile acid, which came over firſt, yielded no air.

I ſubmitted a quantity of *ſpirit of ſalt* to both theſe proceſſes, *viz.* expoſing it to a boiling heat in glaſs tubes, hermetically ſealed, and making the vapour paſs through a red hot earthen tube, but no air was produced in either caſe. In the former caſe, the water ruſhed into, and completely filled, the tube, when it was opened under water; and in the other proceſs the liquor diſtilled was preciſely of the ſame ſpecific gravity, and, no doubt, in all other reſpects, the ſame as before diſtillation; but the acid that remained in the retort was of leſs ſpecific gravity, in conſequence of the acid vapour being expelled by the heat in the form of marine acid air, which appeared not to be affected by a red heat.

Though, in the proceſs with ſpirit of ſalt, the reſult be different from that of thoſe with oil of vitriol and ſpirit of nitre, yet there is an analogy among all theſe three acids in this reſpect, *viz.* that the marine and both the volatile acids of vitriol and nitre are made by impregnating water with the acid vapour, ſo that in its uſual ſtate it may be ſaid to be phlogiſticated as well as theſe.

It was evident that the water in the worm-tub was much more heated by the diſtillation of the ſpirit of ſalt than by that of the oil of vitriol, and eſpecially that of the ſpirit of nitre; ſo that much of the heat by which it had been raiſed in vapour muſt, in the latter caſe, have been *latent* in the air that was

formed; whereas, in the other caſe, it was communicated to the water in the worm-tub.

In one of the proceſſes with boiling ſpirit of ſalt, in a glaſs tube, hermetically ſealed, I had the ſame white vapour dancing in the middle of the tube as in the experiment with the oil of vitriol; but this tube burſt, and I never had the ſame appearance again, though I repeated the experiment ſeveral times for the ſake of it.

The vapour of dephlogiſticated marine acid, which M. BERTHOLLET diſcovered, and with which water may be impregnated as with fixed air, being made to paſs through the hot earthen tube, became dephlogiſticated air as in the following experiment.

Having poured a quantity of ſpirit of ſalt upon ſome manganeſe in a glaſs retort, I heated it as in the preceding experiments with a proper apparatus both for receiving the diſtilled liquor, and the air. I found ſeven-tenths of the air was fixed air, and the remainder very pure dephlogiſticated. The quantity I could not meaſure on account of one of the junctures in the apparatus giving way; but I do not imagine that quite ſo much pure air could be got in this method as from the manganeſe itſelf in a direct proceſs. The liquor received in this diſtillation reſembled ſtrong ſpirit of ſalt in which manganeſe had been put.

This proceſs immediately ſucceeding that in which the glaſs tube, joining the earthen tube and worm-tub, was left full of black matter by the diſtillation of the alkaline liquor (which will be mentioned hereafter), the blackneſs preſently vaniſhed, and the tube became tranſparent as before. On this account, however, it is poſſible that I might receive leſs pure air than I ſhould otherwiſe have done.

Diſtilled

Diſtilled vinegar ſubmitted to this proceſs yielded air two-thirds of which was fixed air, and the reſt inflammable: expending 2 oz. 19 dw. 0 gr. of the acid, I got 1 oz. 19 dw. 0 gr. of a liquor which had a more pungent ſmell than it had before diſtillation. It had alſo ſome black matter in it, and ſome of the ſame remained at the bottom of the retort when the liquor was evaporated to dryneſs. The air I received was 90 oz. meaſures.

Alkaline air is converted into inflammable air in this proceſs as well as by the electric ſpark, but by no means, I think, in ſo great a degree. I put 2 oz. 10 dw. 0 gr. of water pretty ſtrongly impregnated with alkaline air into the retort, and heating it, ſent the vapour through the hot tube; when I collected 2 oz. 3 dw. 0 gr. of liquor, which had a diſagreeable empyreumatic ſmell, as well as that of a volatile alkali, and it was quite opaque with a *black matter*, which ſubſided to the bottom of the veſſel. Alſo the tube through which the air and vapour had been conveyed was left quite black, as mentioned above. One of the junctures of the apparatus not having been air-tight, I did not collect all the air, but it came only at the beginning of the proceſs, and before the tube became black, or any liquor was diſtilled, and it was all ſtrongly inflammable.

I ſhall now recite a few experiments of a different kind from thoſe that have been mentioned above, and more immediately relating to the doctrine of phlogiſton.

It is ſaid, by thoſe who do not admit the doctrine of phlogiſton, that the metals are ſimple ſubſtances, which, having a ſtrong affinity to dephlogiſticated air, imbibe it when they become calces, without parting with any thing. But that ſomething is really parted with in the calcination (as they will call

it) of iron in dephlogiſticated air, appears to me to be very evident, as well as in the proceſs with ſteam.

That fixed air is found in the veſſel in which iron is melted in dephlogiſticated air, I obſerved before; but I never took much care to aſcertain the quantity of it. This I have lately done in many inſtances, and in all of them find it to be much more conſiderable than can be accounted for, by ſuppoſing it to come from plumbago in the very ſmall quantity of iron that I melted; ſo that it muſt neceſſarily have been formed by the phlogiſton from the iron, and the pure air in the veſſel, at the ſame time that the iron became finery cinder by imbibing water from the air; and I have ſhewn, that by far the greateſt part of the weight of this air is water. The experiments were made with a very good burning lens, of ſixteen inches diameter, with which Mr. PARKER has generouſly furniſhed me; and by means of it I can now make theſe experiments, which require a great degree of heat, with much more eaſe and certainty than I could do before.

In 6½ oz. meaſures of dephlogiſticated air I melted turnings of malleable iron till there remained only 1½ oz. meaſure, and of this $\frac{2}{10}$ oz. meaſure was fixed air. In 6 oz. meaſures of dephlogiſticated air, of the ſtandard of 0.2, I melted iron till it was reduced to two-thirds of an ounce-meaſure, of which one-half was fixed air, and the remainder completely phlogiſticated. Again, I melted iron in 7½ oz. meaſures of dephlogiſticated air, of the ſame purity with that in the laſt experiment, when it was reduced to 1½ oz. meaſure, and of this four-fifths was fixed air, and the remainder phlogiſticated. In this caſe I carefully weighed the finery cinder that was formed in the proceſs, and found it to be nine grains, ſo that the iron that had been melted (being about two-thirds of this weight) had

had been about ſix grains. I repeated the experiment with the ſame reſult.

When the dephlogiſticated air is more impure, the quantity of fixed air will always be leſs in proportion. Thus, having melted iron in ſeven ounce meaſures of dephlogiſticated air of the ſtandard of 0.65, it was reduced to 1.6 oz. m.; and of this only one-third of an ounce meaſure was fixed air. This, however, is much more than can come from the plumbago in the iron; but as the production of this fixed air is by many aſcribed to this plumbago, it may be worth while to ſhew by computation that it is impoſſible that it ſhould have this origin. Both the quantity of plumbago in iron, and the quantity of fixed air in plumbago, are much too ſmall for the purpoſe.

From half an ounce of the pureſt plumbago, I firſt got, in a coated glaſs retort, 13 ounce-meaſures of air, of which only three ounce meaſures were fixed air, the reſt being inflammable; then putting it into an earthen tube, I kept it ſome hours in as great a heat as I could produce, and got 22 oz. m. more; and of this alſo only three were fixed, and the reſt inflammable, and the laſt portion was wholly ſo.

But inſtead of ſuppoſing the fixed air that I got to be that which was expelled from the plumbago in the iron, I will ſuppoſe that even the whole of this plumbago afforded only one of the elements of the fixed air, *viz.* phlogiſton, or that which the French chemiſts call *carbone*; and that this principle, by its union with the dephlogiſticated air in the veſſel, forms the fixed air, yet on this moſt unfavourable and improbable ſuppoſition the quantity will be found to be inſufficient.

If 100 gr. of iron contain, according to M. BERGMAN, 0.12 gr. of plumbago, 7 gr. (which is the moſt that in any of the preceding proceſſes I converted into finery cinder) would

contain only 0.0084 gr. of plumbago; and if we ſuppoſe with Mr. KIRWAN, that an hundred cubic inches of fixed air contains 8.14 gr. of phlogiſton, the fixed air produced in one of the above-mentioned proceſſes (*viz.* four-fifths of an ounce-meaſure) would contain .032 gr. of phlogiſton, which is above three times more than the plumbago in the iron could furniſh. It is evident, therefore, that the quantity of fixed air that I found muſt have been formed by phlogiſton from the iron uniting with the dephlogiſticated air in the veſſel.

If, as I have inferred, from burning charcoal of copper in dephlogiſticated air (ſee Experiment, Vol. VI. p. 272.) fixed air conſiſts of 3.45 parts of dephlogiſticated air and 1.5 of phlogiſton, it will be found, that four-fifths of an ounce meaſure of fixed air will contain 0.21 gr. of phlogiſton, which is much more than on the ſuppoſition of Mr. KIRWAN.

Another argument againſt the antiphlogiſtic doctrine may be drawn from an experiment which I made upon Pruſſian blue; if the ſmall quantity of fixed air, that may be expelled from it by heat, be compared with the much greater quantity which is produced when heated in dephlogiſticated air.

Pruſſian blue is generally ſaid to be a calx of iron ſuperſaturated with phlogiſton, though of late it has been ſaid by ſome that it has acquired ſomething that is of the nature of an *acid*. From my experiments upon it, with a burning lens in dephlogiſticated air, I ſhould infer, that the former hypotheſis is true, except that the ſubſtance contains ſome fixed air, which is no doubt an acid; for much of the dephlogiſticated air diſappears, juſt as in the preceding ſimilar proceſs with iron.

I threw the focus of the burning lens upon 2 dw. 5 gr. of Pruſſian blue in a veſſel of dephlogiſticated air, of the ſtandard of 0.53, till all the colour was diſcharged. Being then weighed,

weighed, it was 1 dw. 2 gr. In this proceſs 7¼ oz. of fixed air had been produced, and what remained of the air was of the ſtandard of 0.94. Heating the brown powder to which the Pruſſian blue was reduced in this experiment in inflammable air, it imbibed 8¼ oz. m. of it, and became of a black colour; but it was neither attracted by the magnet, nor was it ſoluble in oil of vitriol and water, as I had expected it would have been.

Again, I heated Pruſſian blue in dephlogiſticated air, of the ſtandard of 0.2, without producing any ſenſible increaſe of its bulk, when I found three ounce meaſures of it to be fixed air, and the ſtandard of the reſiduum, with two meaſures of nitrous air, was 1.35. The ſubſtance had loſt eleven grains, the greateſt part of which was evidently water.

To determine what quantity of fixed air Pruſſian blue would yield by mere heat, I put half an ounce of it into an earthen tube, and got from it 56 oz. m. of air, of which 16 oz. m. were fixed air, in the proportion of one-third in the firſt portion, and one-fourth in the laſt. The remainder was inflammable. There remained 5 dw. 20 gr. of a black powder, with a very little of it (probably the ſurface) brown.

Comparing theſe experiments, it will appear, that the fixed air procured by means of Pruſſian blue and dephlogiſticated air muſt have been formed by phlogiſton from the Pruſſian blue and the dephlogiſticated air in the veſſel: for if 240 gr. of this ſubſtance yield 16 oz. meaſures of fixed air, ten grains of it (which is more than was uſed in the experiment) would have yielded only 0.6 oz. m. Nor is it poſſible to account for the diſappearing of ſo much dephlogiſticated air, but upon the ſuppoſition of its being employed in forming this fixed air.

XXIV. *On the Production of nitrous Acid and nitrous Air.* *By the Rev.* Iſaac Milner, *B. D. F. R. S. and Preſident of* Queen's College, Cambridge.

Read July 2, 1789.

1. IT has been known for ſome time, that a relation ſubſiſts between nitrous acid and volatile alkali. The latter has frequently been produced by help of the former; but I do not recollect that, in any inſtance, the volatile alkali has been proved to contribute to the formation of nitrous acid or nitrous air. Some caſes, however, have occurred to me where this evidently happens; and they appear ſo new and extraordinary, that I cannot but think they deſerve the attention of philoſophical chemiſts. The hiſtory of the experiments I allude to is as follows.

2. As ſoon as I had heard of the production of inflammable air by the tranſmiſſion of ſteam through red-hot iron tubes, I had the curioſity to try whether ſome other ſubſtances in the form of air or vapour might not, by a ſimilar proceſs, undergo material alterations. In particular, the nitrous acid ſeemed well to deſerve a trial, both on account of the obſcurity and difficulties attending the theory of its production, and alſo of its important and extenſive uſefulneſs in chemiſtry.

In the relation of my experiments on this head, it will be unneceſſary to mention the exact *quantity* of acid or of air expended or generated, though I noted thoſe quantities pretty accurately

accurately at the time; for the main point I have in view in this deſcription, is to aſcertain the *nature* of the *changes* which took place; and theſe do not depend upon the quantities of aerial fluids, but upon their properties. Beſides, whoever ſhall repeat theſe experiments will find the relative *quantities* to vary very much, according to the manner of operating; and therefore, for the ſake of brevity, I omit to mention them entirely.

3. I began with boiling a little ſtrong nitrous acid in a ſmall retort, the neck of which was cloſely luted to one end of a gun-barrel. The other end of it was immerſed ſometimes in water, and ſometimes in quickſilver, and eighteen or twenty inches of the middle part was ſurrounded with burning charcoal in a proper furnace. In this manner the vapour and fumes of the boiling acid were tranſmitted through the red-hot tube, and the produce received at the end in the uſual manner.

When the acid was made to boil violently, there paſſed over a conſiderable quantity of undecompoſed red nitrous vapour, together with a mixture of nitrous and phlogiſticated airs.

When the proceſs was conducted more moderately, there was leſs nitrous vapour; and in the mixture of airs which was received in the glaſs veſſels, there was a much greater proportion of phlogiſticated air.

4. In order to increaſe the ſurface of the red-hot iron, and effect a more complete decompoſition of the nitrous vapour, the gun-barrel was crammed full of iron filings. The experiments were repeated with great caution, and almoſt the whole of the produce was found to be phlogiſticated air. It is however proper to mention, that, notwithſtanding every poſſible care, ſtill there will generally be in ſome degree an admixture

of nitrous air, and frequently of dephlogiſticated nitrous air. But I am ſatisfied that if the iron tube were ſufficiently long, ſo that a very large portion of it might be heated red-hot, all the air received in this manner from any quantity of nitrous acid ſlowly boiled would be found of that ſpecies called phlogiſticated air.

5. Theſe experiments ſeem altogether analogous to thoſe of Dr. PRIESTLEY, in which nitrous air, by expoſure to iron, is converted firſt into dephlogiſticated nitrous air, and afterwards into phlogiſticated air. The only difference ſeems to be, that in my experiments the effect is brought about ſuddenly; whereas in the method of expoſition to iron much time is required. And farther, in my method of operating, it is very difficult to conduct the proceſs ſo as to inſure the production of that ſingular ſpecies of air called dephlogiſticated nitrous air. If the acid boil very quick, the product is nearly all nitrous vapour and nitrous air. If it boil very ſlow, and a ſufficient quantity of the iron tube be well heated, then the decompoſition is almoſt complete, and little is received but phlogiſticated air. In both caſes, the progreſs of the converſion of nitrous acid to the ſtate of phlogiſticated air ſeems to be the ſame. Firſt, nitrous air is formed, then dephlogiſticated nitrous air, and laſtly phlogiſticated air. This, I ſay, ſeems to me to be the natural order of the converſion, though I do not deny, that in the rapid manner of operating with the red-hot iron tube ſome particles of nitrous acid or vapour may probably be *inſtantly* changed into phlogiſticated air. And even allowing this to be the caſe, the fact may eaſily be explained, by ſuppoſing the ſucceſſive approaches to phlogiſticated air to be made in too ſmall ſpaces of time to be obſerved; nor does it in the leaſt invalidate the general concluſion, that nitrous

air

air is nearer the ſtate of phlogiſticated air than nitrous acid or nitrous vapour; and that dephlogiſticated nitrous air is ſtill nearer. It is very difficult to decide with certainty what the changes are which the particles of the acid undergo in their paſſage through different parts of the hot tube.

From what has been ſaid, the moſt common proceſs will probably appear to be, that a particle of the acid in the form of vapour firſt generates nitrous air; that the parts of this are applied to freſh ſurfaces of hot iron, and ſuddenly changed into dephlogiſticated nitrous air; which, laſtly, is applied to ſtill freſh ſurfaces of the tube or fragments of iron, and ſo converted into phlogiſticated air. When theſe ſucceſſive contacts with freſh ſurfaces of hot iron are not ſufficiently numerous or exact, it is not unnatural to conclude, that ſome portion of air may eſcape not perfectly decompoſed.

6. Theſe conſiderations induced me to alter the proceſs a little. Inſtead of boiling the acid in the retort, I put ſome thin pieces of copper into a phial, poured nitrous acid upon them, and forced the nitrous air, as it was generated, to paſs through the red-hot tube. The event anſwered my expectation; the decompoſition was effected in this way eaſier than in the former.

But before I made this experiment, I examined what would be the effect of mere heat upon nitrous air, as I had already learned from the experiments of others, that nitrous acid, forced in the form of ſteam through red-hot tubes of clay or glaſs, underwent the moſt important alterations.

What might be the effect of long continued expoſure to a red heat I cannot ſay; but I was ſoon convinced, that nitrous air might be forced through a red-hot glaſs tube, without ſuffering any material change.

7. Laſtly, I determined to try the effect of the gun-barrel upon dephlogiſticated nitrous air, as from all that I had ſeen it ſeemed reaſonable to expect, that this ſpecies of air would be the eaſieſt reduced to the ſtate of phlogiſticated air. For this purpoſe, I diluted a ſaturated ſolution of copper in the nitrous acid, and put pieces of iron wire into it, and as the neck of the retort which contained the ſolution was luted to one end of the gun-barrel, the dephlogiſticated nitrous air was expoſed in its paſſage to the action of the red-hot tube, and alſo to the ſurfaces of the red-hot iron turnings which it contained. In this caſe, when the proceſs is conducted with proper care, all the air which is received at the other end of the tube will be found phlogiſticated.

8. When the air received at the end of the gun-barrel was in the laſt mentioned ſtate, *viz.* perfectly phlogiſticated, I have frequently obſerved a white fume iſſuing along with the air, and ſometimes aſcending through the water or mercury into the glaſs receivers. Upon examining this white fume, I ſoon perceived by the ſmell that it contained volatile alkali. I was much ſtruck with the obſervation, and immediately recollected Dr. PRIESTLEY's relation of a ſimilar production by expoſing nitrous air to pieces of iron.

9. Moſt of the experiments hitherto related were made in the ſummer of 1786; in general they agree with thoſe of Dr. PRIESTLEY; the changes and productions are much the ſame, and the only new circumſtance is, as was obſerved at art. 5. The ſame effects are brought about *inſtantly* by the action of red-hot iron, which require much time by the method of ſimple expoſure to cold iron.

For which reaſon, though it gave me much pleaſure at the time to ſee ſuch curious tranſmutations brought about in a few minutes,

minutes, yet it ſcarcely appeared worth while to trouble the Royal Society with a detail of the experiments; and I only preſume to do it now, becauſe the conjectures which I then formed have been ſufficiently verified by future experiments.

The conjectures were as follow:

10. Almoſt immediately upon ſeeing the volatile alkali produced by means of nitrous acid and metals, I conceived the poſſibility of inverting the order of the proceſs, and of producing nitrous acid or nitrous air by the decompoſition of volatile alkali. I knew of no experiments wherein this had been done, or any thing like it; yet as volatile alkali was beyond all diſpute produced in the method juſt deſcribed, and as the iron turnings and inſide of the gun-barrel were left after the operation in a ſtate of calcination, it ſeemed not unnatural to ſuppoſe, that by forcing volatile alkali through the red-hot calces of ſome of the metals, nitrous acid or nitrous air might be produced. Some of my friends, to whom I mentioned the idea, conſidered it as a random conjecture. However, I made a memorandum of it as a thing that deſerved to be tried, though in fact I neglected for near two years actually to make the trial. It was ſome time in the month of March, 1788, that the calx of manganeſe on account of its very great infuſibility, and its yielding abundance of dephlogiſticated air, occurred to me as a very proper ſubſtance for the purpoſe. I immediately crammed a gun-barrel full of powdered manganeſe; and to one end of the tube I applied a ſmall retort, containing the cauſtic volatile alkali. As ſoon as the manganeſe was heated red-hot, a lighted candle was placed under the retort, and the vapour of the boiling volatile alkali forced through the gun-barrel. Symptoms of nitrous fumes and of nitrous air ſoon diſcovered themſelves,

and

and by a little perſeverance I was enabled to collect conſiderable quantities of air, which on trial proved highly nitrous. I have ſince frequently repeated this experiment, and have always in ſome degree ſucceeded. Much depends on the *kind* of manganeſe employed, much on the heat of the furnace, and much on the patience of the operator; as theſe are varied, there will be great variations of the products. A minute detail of all the particulars of my experiments ſeems unneceſſary; but it may be proper to give a general account of the principal facts, and of the methods which were uſed to avoid erroneous concluſions.

11. In general I made uſe of clean gun-barrels with which no previous experiments had been made. The manganeſe was uſed in rough powder; for when it is too finely powdered, the tube is choaked, and the air cannot paſs.

In ſome experiments I applied the vapour of the volatile alkali directly to the hot manganeſe. In others I ſuffered the manganeſe to remain a conſiderable time in a red heat before I made the volatile alkali, contained in the retort at the end of the tube, to boil; and by this means I informed myſelf of the nature of the airs which the manganeſe yielded *per ſe*.

In neither caſe could I ever perceive the leaſt appearance of nitrous acid or nitrous air till the volatile alkali was uſed. Manganeſe, *per ſe*, gives airs of different kinds (but chiefly fixed and dephlogiſticated airs) as ſoon as ever it is ſubjected to a conſiderable heat; but nothing nitrous comes from it, either on the firſt application of heat, or after it has been continued a long time; and I examined this point with great diligence. But ſoon after the volatile alkali begins to be applied, the jars in which the air is received will frequently turn ſlightly

ſlightly red, and this redneſs will increaſe on admitting atmoſpherical air.

The cauſtic alkali ſhould be ſtrong, and as far as I have obſerved the longer the proceſs is continued, the ſtronger will be the nitrous air produced. At leaſt this evidently appeared to be the caſe in ſeveral inſtances, where the operation was continued for a long time.

In moſt inſtances, on the very commencement of this proceſs, a ſmall jar of the air thus collected diſcovers by the *ſmell* a nitrous impregnation. But it ſometimes happens, that ſeveral jars of air may be collected, and the admiſſion of atmoſpherical air to them will not produce a ſenſibly red colour.

Here, however, there exiſts a cauſe of deception againſt which the operator ought to be on his guard, leſt he ſhould conclude that no nitrous air is formed, when in reality there is a conſiderable quantity. The volatile alkali, notwithſtanding every precaution, will frequently paſs over in great quantities undecompoſed. If the receivers are filled with water, a great part of this will indeed be preſently abſorbed; but ſtill ſome portions of it will mix with the nitrous air formed by the proceſs. Upon admitting the atmoſpherical air, the nitrous air is decompoſed, and the red nitrous fumes inſtantly combine with the volatile alkali. The receivers are preſently filled with white clouds of nitrous ammoniac; and in this manner a wrong concluſion may eaſily be drawn, from the want of the orange colour of the nitrous fumes. A conſiderable quantity of nitrous air may have been formed, and yet no orange colour appear, owing to this circumſtance; and therefore it is eaſy to underſtand how a ſmall quantity of nitrous air may be moſt effectually diſguiſed by the ſame cauſe.

12. These observations are made principally for the sake of those who may wish to repeat these experiments. The main point to be established, is the actual formation of nitrous air by this method. And this truth I consider as proved beyond all controversy; for by continuing the process patiently, and applying repeatedly fresh portions of strong volatile alkali to the same manganese, kept constantly hot in the gun-barrel, I have often collected large jars of air, which was proved to be highly nitrous by mixture with atmospherical or with dephlogisticated air.

13. It is not easy to say, whether in this process dephlogisticated nitrous air, or even nitrous acid itself, be not sometimes immediately formed by the action of the volatile alkali on the manganese. Traces of the former, in some instances, seem to discover themselves; but I do not speak decidedly on this head. As to the latter, it is very certain, that fumes of the nitrous acid often circulate in the jars that receive the air. But possibly these fumes may arise from the decomposition of nitrous air, by means of the superfluous dephlogisticated air of the manganese.

14. The steam of boiling water was applied to red hot manganese in a similar way; not the least nitrous appearance; but the fixed and dephlogisticated airs were generated much more plentifully than when the manganese was urged by mere heat. When these airs had been collected in large quantities, the volatile alkali was applied as before to the residuum of the manganese, and nitrous air soon appeared.

15. As manganese is known to produce a very extraordinary change upon spirit of salt in a moderate heat, it seemed not improbable, that a still greater change might take place by working in this method. Accordingly I forced the vapour of

boiling ſpirit of ſalt to paſs through red-hot manganeſe. This experiment did not anſwer my expectation; the product was a mixture of fixed and inflammable air. But it deſerves to be noticed, that even in this caſe, after the effect of the ſpirit of ſalt had been tried for a long time, a production of nitrous air upon the application of volatile alkali to the ſame manganeſe ſoon took place.

16. As there are many other ſubſtances beſides the calx of manganeſe, which are known, *per ſe*, to afford dephlogiſticated air, or a mixture of this with fixed air, it was natural to conclude from analogy, that ſuch ſubſtances upon the application of volatile alkali would not fail to afford nitrous air.

It is beſt, however, in theſe matters to truſt as little as poſſible to conjectures, and to bring every opinion to the teſt of experiment. Manganeſe is ſo ſingular a ſubſtance, that it is perhaps hardly ſafe, from what happens in making trials with it, to infer in any inſtance of another calx of a metal a ſimilarity of effect. Red lead, however, is known to agree in ſuch a variety of chemical effects with manganeſe, that I find it difficult to perſuade myſelf that the volatile alkali properly applied to it would not yield nitrous acid or nitrous air; yet I have hitherto in vain attempted to bring this about. The red lead, indeed, melts during the proceſs, flows into the cooler parts of the tube, and often choaks the paſſage of the air; but in ſome trials a great deal of air has been collected before that happened, and without any ſymptom of a nitrous mixture. It ſeems difficult to explain the reaſon of the failure; perhaps with a better adapted apparatus, and more perſeverance, either the production in queſtion may be obtained, or the cauſe of the failure diſcovered.

17. With calcined green vitriol I had much better ſucceſs. The ſalt was calcined to whiteneſs, and put into a gun-barrel; and, after ſeveral trials of forcing the volatile alkali through the hot tube, I procured by the operation ſome ounces of ſtrong nitrous air.

So extraordinary an effect would no doubt have proved highly grateful to the ancient chemiſts, and have been by them denominated a tranſmutation.

In the courſe of my enquiries, I conſidered this experiment as important, becauſe it proved, that the ſame combinations might take place when ſubſtances were made uſe of different from manganeſe.

18. As calcined green vitriol, *per ſe*, in a ſtrong heat yields dephlogiſticated air, I had now no doubt but that any ſubſtance which had this property might, by ſimilar treatment, be made to afford nitrous air.

But in this ſuppoſition I was entirely miſtaken. The volatile alkali was applied to ſome calcined alum at the moment when it was yielding in a ſtrong heat plenty of dephlogiſticated air. The product was an aſtoniſhing quantity of inflammable air, mixed with hepatic air and actual ſulphur. The reſiduum of the alum had a ſtrong hepatic ſmell, and contained particles of perfectly formed ſulphur.

Moſt of theſe experiments, if not all, were repeated in earthen tubes inſtead of gun-barrels, and with the ſame ſucceſs.

19. It now only remains, that I ſhould briefly propoſe what occurs to me as the probable theory and explanation of the facts related.

The ingredients which enter into the compoſition of nitrous acid ſeem to be the two principles or elements of the atmoſphere,

ſphere, *viz.* phlogiſticated and dephlogiſticated air. That this is the caſe, there ſeems little reaſon to doubt. Both the compoſition and decompoſition of nitrous acid renders the ſuppoſition probable. For,

1. Nitrous air and dephlogiſticated air by mixture produce nitrous acid; and nitrous acid, by mere heat, is converted into a mixture of phlogiſticated and dephlogiſticated airs.

2. Nitrous air, by the methods already related, is changed into phlogiſticated air, and theſe methods ſeem to conſiſt in abſtracting from the nitrous air a quantity of dephlogiſticated air.

3. When nitrous acid and nitre are produced in a natural way, the proceſs is not well underſtood; but the preſence of the atmoſphere is known to be neceſſary.

4. Mr. CAVENDISH's experiment is deciſive on this point. The union of the two airs in queſtion is effected by means of the electrical ſpark, and nitrous acid is the product.

In the next place we are to conſider, that volatile alkali contains phlogiſticated air; for,

1. Volatile alkali, by mere heat, or by the electrical ſpark, is changed into a mixture of phlogiſticated and inflammable air; and,

2. The reſiduum of volatile alkaline air, after the calces of lead have been revived in it, is phlogiſticated air.

Therefore, when volatile alkali, in the form of fume or air, is applied to red-hot manganeſe, or calcined green vitriol (ſubſtances which are then yielding dephlogiſticated air), with theſe facts in view, it ſeems not difficult to conceive, that one of the ingredients of the alkali, *viz.* phlogiſticated air, ſhould combine with dephlogiſticated air, and form nitrous acid or nitrous air. If nitrous acid be formed, it will indeed in that

heat, as has been obſerved, be inſtantly decompoſed; but if the effect of the union be nitrous air, that will ſuſtain the heat without decompoſition. How it happens, that nitrous air ſhould be formed, and not nitrous acid, or what the reaſon is, that nitrous air can ſuſtain a red heat without decompoſition, when nitrous acid cannot, I am unable to ſay; and it is better to acknowledge our ignorance than advance groundleſs conjectures. So much, I think, may be pronounced as certain, *viz.* that nitrous air contains leſs dephlogiſticated air than nitrous acid; becauſe it requires the addition of dephlogiſticated air to become nitrous acid.

And, laſtly, if I miſtake not, the experiment with the calcined alum proves, that, in order to produce nitrous air, it is not ſufficient merely to apply volatile alkaline air to a ſubſtance which is actually yielding dephlogiſticated air.

Perhaps the preſence of another ſubſtance is required, which has a ſtrong attraction for phlogiſton. Perhaps, in the experiments with the calces of manganeſe and of iron, the inflammable principle of the volatile alkali combines with the calces of the metals, and the phlogiſticated air, the other component part, unites with the dephlogiſticated air; and if ſo, it ſeems not improbable to ſuppoſe, that when alum is made uſe of, the inflammable principle of the volatile alkali having little or no attraction for clay, the baſis of the alum, ſhould combine with its acid and form ſulphur. If this reaſoning be true, then it follows, that the vitriolic acid has a ſtronger affinity to the inflammable principle than it has to phlogiſticated air; and the proceſs with the green vitriol and manganeſe is to be explained by the operation of a double affinity: the inflammable principle of the volatile alkali joins with the calx of iron, the

baſis

baſis of the vitriol, or with the manganeſe, and the phlogiſticated air with the dephlogiſticated air produced by the acid in the red heat.

Thoſe who chuſe to reject the doctrine of phlogiſton muſt make the neceſſary alteration in theſe expreſſions; but the reaſoning will be much the ſame.

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*Nicholſon*, Mr. William, on electricity, p. 265.

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*Phlogiſton*, experiments relating to the doctrine of, p. 295.

*Phoſphorus*, after the aſcenſion of it in dephlogiſticated air, there is a conſiderable quantity of fixed air in the reſiduum, p. 16.

*Piazzi*, Rev. Joſeph, reſult of calculations of the obſervations made at various places of the eclipſe of the ſun, which happened June 3, 1788, p. 55.

*Point*. A force acting at a given point may be reſolved by an infinite number of ways into two, three, or more forces acting at the ſame point, either in the ſame or diſferent planes with the given force and each other; and, *vice verſâ*, any number of ſuch forces acting in the ſame or different planes may be reduced into one, p. 185. Example proving this aſſertion, ibid. See *Problem*.

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*Preſents*, liſt of, made to the Royal Society from November 1788 to July 1789, p. 314.

*Prieſtley*, Rev. Dr. Joſeph, objections to the experiments and obſervations relating to the principle of acidity, the compoſition of water, and phlogiſton, conſidered; with further experiments and obſervations on the ſame ſubject, p. 7. On the phlogiſtica-

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*Saturn* (the planet) has a ſixth ſatellite revolving round it, p. 255.

*Saunders*, Robert, on the vegetable and mineral productions of Boutan and Thibet, p. 79.

*Sclub*, here is a hot well much frequented by people with venereal complaints, rheumatiſm, and all cutaneous diſeaſes, p. 94. State of the thermometer when immerſed in the water of this well, ibid. Its water contains a portion of hepar ſulphuris, ibid.

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